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**Rocky Mountain
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Fort Collins,
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General Technical
Report RM-180

An Analysis of the Range Forage Situation in the United States: 1989–2040

A Technical Document Supporting the 1989 USDA Forest Service RPA Assessment

Linda A. Joyce

Preface

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), P.L. 93-378, 88 Stat. 476, as amended, directed the Secretary of Agriculture to prepare a Renewable Resources Assessment by December 31, 1975, with an update in 1979 and each 10th year thereafter. This Assessment is to include "an analysis of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands with consideration of the international resource situation, and an emphasis of pertinent supply, demand and price relationship trends" (Sec. 3.(a)).

The 1989 RPA Assessment is the third prepared in response to the RPA legislation. It is composed of 12 documents, including this one. The summary Assessment document presents an overview of analyses of the present situation and the outlook for the land base, outdoor recreation and wilderness, wildlife and fish, forest-range grazing, minerals, timber, and water. Complete analyses for each of these resources are contained in seven supporting technical documents. There are also technical documents presenting information on interactions among the various resources, the basic assumptions for the Assessment, a description of Forest Service programs, and the evolving use and management of the Nation's forests, grasslands, croplands, and related resources.

The Forest Service has been carrying out resource analyses in the United States for over a century. Congressional interest was first expressed in the Appropriations Act of August 15, 1876, which provided $2,000 for the employment of an expert to study and report on forest conditions. Between that time and 1974, Forest Service analysts prepared a number of assessments of the timber resource situation intermittently in response to emerging issues and perceived needs for better resource information. The 1974 RPA legislation established a periodic reporting requirement and broadened the resource coverage from timber to all renewable resources from forest and rangelands.

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Acknowledgments

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CHAPTER 1: THE RANGE RESOURCE

INTRODUCTION

Range and range resources are many things to many people. In the broad view, range is a type of land, a kind of vegetation, and a way of management (Range Inventory Standardization Committee 1983, U.S. Senate 1936). Previous studies or assessments on the Nation's range resources have had broad objectives, such as the Forest-Range Environmental Study (USDA Forest Service 1972), or the 1980 Assessment (USDA Forest Service 1980), or have focused on specific issues, such as range condition (U.S. General Accounting Office 1988).

The mandate for the present assessment is the Resource Planning Act (RPA) of 1974 which directs the Forest Service (FS) to prepare an Assessment of the Nation's renewable resources every 10 years. As directed by this legislation, the assessment shall include but not be limited to "an analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply and demand and price relationship trends".[2] The present report analyzes the range resource from a national perspective, includes public and private lands, and uses information collected by other public agencies as well as the Forest Service.

Chapter 1 describes the current status of the range resource, the multiple outputs currently produced from range vegetation, the land area and productivity of range vegetation. The factors affecting supply and demand of range outputs (Chapters 2 and 3) are used to develop a projection of future supply and demand (Chapter 4). The social, economic, and environmental implications of this future scenario are reviewed in Chapter 5, opportunities for and obstacles to managing the range resource are discussed in Chapter 6, and the implications to all Forest Service programs, including the National Forest System (NFS) renewable resource program, Research, and State and private forestry programs are discussed in Chapter 7. Terms used in this report are defined in the Glossary (Appendix D). Scientific and common names for all plants mentioned in this report are given in Appendix A. Scientific and common names for all animals mentioned in this report are given in Flather and Hoekstra (in press).

[2]*Forest and Rangeland Renewable Resources Planning Act. Act of Aug. 17, 1974. 88 Stat. 476, as amended; 16 U.S.C. 1600-1614.*

Four Assessment regions are used to present resource data: the Northern (NO), Southern (SO), Pacific Coast (PC), and Rocky Mountain (RM). For the present report, a finer delineation of the western regions is used, where possible (fig. 1). The Pacific Coast region is broken into the Pacific North (PN) and California (CA) regions. The Rocky Mountain is broken into the Northern Rocky (NR) Mountain and the Southwest (SW) regions. Alaska and Hawaii are treated separately.

RANGE AND RANGE RESOURCES

Range vegetation is defined as grasses, grass-like plants, forbs, and shrubs. This definition includes introduced species that are managed like native plants. When the vegetation (climax or natural potential) is dominated by range vegetation, the land is referred to as rangeland. Whereas rangelands predominate in western United States as natural grasslands, shrublands, savannas, deserts, tundra, alpine, coastal marshes, and wet meadows, rangeland also occurs as tallgrass prairie, marshes, and wet meadows in eastern United States. Riparian ecosystems, and plant communities dominated by introduced species are also considered rangelands. Range vegetation is most commonly associated with grasslands and shrublands, but forest lands also support an understory of grasses, grass-like plants, forbs, and shrubs. Range vegetation forms the basic building block in the production of multiple resources from forest and rangelands.

In this document, the diversity of vegetation on forest and rangeland is described using the 34 ecosystems of the Forest and Range Environmental System (FRES) (fig. 2, table 1). This classification system is based on broad groupings of the Küchler (1964) communities and forest and woodland types from the FS survey (USDA Forest Service 1967). The mountain meadow vegetation type, an important forage source, was added to Küchler's system and this amended classification was renamed *Potential Natural Communities* (PNC) to mark the distinction from Küchler's classification (Mitchell and Joyce 1986). The PNC represents the biotic community that would become established if all successional sequences proceeded without interference by humans under the

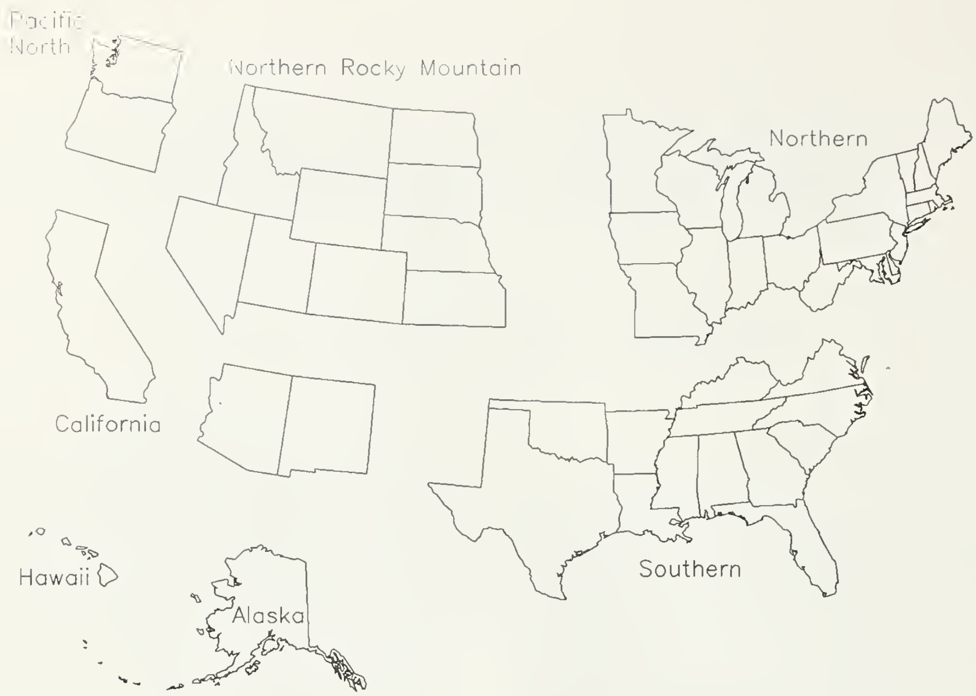


Figure 1.—Assessment regions of the United States.

Source: Garrison and others.

Figure 2.—FRES ecosystems of the United States (see table 1 for explanation of numerals).

present environmental conditions (Range Inventory Standardization Committee 1983). A brief description of each FRES ecosystem is given in Appendix B.

Climatic, geological, and elevational differences across the United States result in the diversity of ecosystems from spruce-fir in Maine, to wet grasslands in Florida, and to chaparral mountain shrub ecosystems in California (fig. 2). For areas in the western United States, the environmental heterogeneity of the landscape induces a mixture of ecosystems within a short geographic distance, necessitating a listing of these types, rather than a finer delineation in figure 2. The diversity of vegetation across the nation's landscape gives an indication of the diversity of renewable resources from forest and rangelands.

Table 1.—Explanation of FRES ecosystems shown in figure 1.

Number	Ecosystem	Number	Ecosystem
10	White-red-jack pine	27	Redwood
11	Spruce-fir	28	Western hardwoods
12	Longleaf-slash pine	29	Sagebrush
13	Loblolly-shortleaf pine	30	Desert shrub
14	Oak-pine	31	Shinnery
15	Oak-hickory	32	Texas savanna
16	Oak-gum-cypress	33	Southwestern shrubsteppe
17	Elm-ash-cottonwood	34	Chaparral-mountain shrub
18	Maple-beech-birch	35	Pinyon-juniper
19	Aspen-birch	36	Mountain grasslands
20	Douglas-fir	37	Mountain meadows[1]
21	Ponderosa pine	38	Plains grasslands
22	Western white pine	39	Prairie
23	Fir-spruce	40	Desert grasslands
24	Hemlock-Sitka spruce	41	Wet grasslands
25	Larch	42	Annual grasslands
26	Lodgepole pine	43	Alpine

[1]*Not mapped.*
Source: Garrison et al. 1977.

MULTIPLE RESOURCE PRODUCTION ON FOREST AND RANGELANDS

The many products flowing from management of the Nation's forest and rangelands are not independent of nor are they produced in constant relation to each other. This relation can best be described as joint production, wherein multiple inputs are combined to produce multiple outputs. The management of these multiple inputs to produce these multiple outputs is range management. Range management includes:

- — determining suitability of vegetation for multiple resource uses;
- — designing and implementing range vegetation improvement practices;
- — understanding social and economic effects of management alternatives;
- — controlling range insects;
- — determining wildlife, recreational, wild horse and burro, and livestock carrying capacities;
- — protecting soil stability;
- — reclaiming disturbed areas;
- — designing and controlling livestock management systems;
- — managing and controlling undesirable range vegetation;
- — coordinating management activities with other land and resource managers;
- — maintaining environmental quality including soil, water, and air (USDA Forest Service 1987c).

Forage is browse and herbage which is available and may provide food for grazing animals or be harvested for feed (Range Inventory Standardization Committee 1983). Range is commonly perceived as producing only forage for livestock. Although livestock grazing is an important use of grazinglands, both forest and rangeland, livestock grazing is not the only use and in some parts of the world is not the most important or best economic or social use of rangelands (Busby 1987). Range outputs and range management are broader issues than domestic livestock. The diversity of outputs from range ecosystems includes forage for both domestic and wild herbivores, firewood and specialty wood products, seed sources for agricultural or reclamation or landscaping purposes, minerals, water quality and quantity, air quality, open space, threatened and endangered plants and animals, genetic material, recreational use, plant and animal diversity, human community stability, and scenic quality. All plant and animal species that depend on rangeland or range vegetation are dependent on range management and must be considered as a product or output of range management. The production of timber and range vegetation, or wild and domestic herbivores, are interdependent in that the management for one output affects the yield of the other. Thus, the management of the Nation's forests and rangelands must recognize tradeoffs or enhancements across resource production opportunities (Hof and Baltic 1988).

The importance, and ultimately the use, of rangelands is often determined by cultural factors in society (Box 1988). Hunter-gather societies and pastoral economies value food production from rangelands. Urban societies value rangelands and forests for clean water production and recreation opportunities. Increased human densities in developed countries raise the question of waste disposal on rangelands while placing a higher value on wilderness for recreation. To reach and maintain these desired objectives while protecting fragile soils and watersheds, the managers of range vegetation must apply knowledge, skills, and techniques based on ecological principles. The joint products that result from range management are important outputs that need to be recognized as goals, objectives, benefits, and uses of the range

resource. A review of some of the current outputs from rangelands and forests follows.

Agricultural, Reclamation, and Landscaping Uses of Range Plants

Interest in the harvest and cultivation of native plants is increasing as society seeks less water-consuming or low maintenance plants for agriculture, land reclamation, and landscaping (Aldon et al. 1987, Goodin and Northington 1985, Hinman 1984, Patton et al. 1986). Range plants are harvested or cultivated for oil, rubber, fruits, vegetables, nuts, grains, medicines, ornamentals, firewood, and specialty wood products (table 2). Cacti are utilized for fruit, green vegetables, forage, fodder, gums for adhesives and thickening foods, strong fibers and ornamentals (Russell and Felker 1987, Vietmeyer 1986). The harvest of prickly pear cactus fruit in Mexico is more than twice the world's harvest of apricot, papaya, strawberries, or avocados (Vietmeyer 1986). Seed from jojoba, a southwestern shrub, yields a valuable lubricating oil (fig. 3). In 1986, the combined harvest of jojoba seed for the United States, Mexico, and Israel was 820 metric tons; a substantial increase over the 12 metric tons harvested in 1976 (Gillis 1988). Guayule, another southwestern shrub, has supplied significant quantities of rubber during previous world wars (Foster and Moore 1987); other plants such as buffalo gourd, gopher plant, and gumweed offer possible sources for oil or rubber (Hinman 1984, Hoffman and McLaughlin 1986, Johnson and Hinman 1980, Patton et al. 1986). Increasing numbers of urban centers in the western United States encourage the use of xeric landscaping to reduce water use. Water use efficiency is much greater for some native plants than plants traditionally used

Table 2.—Resource outputs from range ecosystems.

FRES ecosystem	Plant value	Herbage production (pounds per acre)	Large herbivores	Threatened and endangered animal species
Sagebrush	Forage, browse	0–2,000	Deer, pronghorn, wild horses and burros, sheep, cattle	Utah prairie dog
Desert shrub	Mesquite-fuelwood, charcoal, forage, browse, ornamental cactus, rubber, oil	0–1,000	Deer, pronghorn, bighorn sheep, wild horses and burros, sheep, goats, cattle	Masked bobwhite Sonoran pronghorn
Shinnery	Forage, browse	500–2,000	Deer, cattle	
Texas savanna	Mesquite-fuelwood, charcoal, forage, browse, rubber	0–3,000	Deer, cattle, sheep, goats	Jaguarundi Ocelot Northern aplomado falcon
Chaparral-mountain shrub	Acorns, forage, browse	0–2,000	Deer, wild horses and burros, goats	California condor San Joaquin kit fox
Pinyon-juniper	Christmas trees, fuelwood, pine nuts, fence posts, chips, forage, browse	0–800	Deer, elk, cattle	Thick-billed parrot
Mountain grasslands	Forage	1,000–2,000	Deer, elk, pronghorn, cattle, sheep	
Mountain meadows	Forage	0–4,000	Deer, elk, moose, cattle	
Plains grasslands	Wildflowers, landscaping, forage	0–2,000	Deer, pronghorn, cattle, sheep	Black-footed ferret Northern swift fox
Prairie	Wildflowers, landscaping, forage	1,500–6,000	Deer, pronghorn, cattle	Attwater's prairie chicken Northern swift fox Red wolf
Desert grasslands	Ornamental cactus, landscaping, forage	0–1,000	Pronghorn, deer, cattle, sheep	Masked bobwhite
Wet grasslands	Forage	0–12,000	Deer, cattle	Everglades kite Whooping crane Attwater's prairie chicken
Annual grasslands	Forage	0–4,400	Deer, wild horses and burros, cattle	San Joaquin kit fox Giant kangaroo rat
Alpine	Forage	0–1,200	Deer, elk, bighorn sheep, sheep	Grizzly bear

Figure 3.—Jojoba growing in association with saguro and cactus on Southwestern rangelands.

in urban landscaping (Front Range Xeriscape Task Force [n.d.]). Ecosystems particularly valuable for their landscaping resources are the prairie, plains and desert grassland ecosystems (table 2).

Initially, native seed sources or plants had been difficult to obtain because so little commercial work with arid species had been done. Mined land reclamation research has increased the availability of seed and plant sources. Government conservation programs that encourage the planting of cropland into native range also increase the demand for native plant seeds (Hijar 1988). Commercial nurseries offer an increasing number of native grasses, forbs, shrubs, and trees capable of withstanding long periods of dry weather (Diekelmann et al. 1986, Wallace et al. 1986).

Forage for Wild and Domestic Herbivores

Herbivores, animals that feed on plants, include wildlife such as elk, deer, and antelope, and livestock such as sheep, horses, goats, and cattle. Nearly all forest and rangeland ecosystems provide forage for wild and domestic herbivores. Forage production varies from less than 200 lbs/acre in dense forest stands (table 3) to greater than 2,000 lbs/acre in many grassland ecosystems (table 2). Greater numbers and more diversity in wild and domestic herbivores are found in ecosystems that provide greater amounts of forage and browse.

At least part of the feed mix for domestic horses, sheep, cattle, and goats and all of the feed mix for wild herbivores is forage produced on pasture, range, or forest land. Grazed roughages are forage harvested by grazing or browsing forest, rangeland, or pasture whereas harvested forages are mechanically harvested from pasture, haylands, or croplands seeded to forage crops. Harvested forages are important in providing feed for livestock during winter when little grazed roughages are available, or when forage is not readily accessible, such as for recreational horses in suburban areas. Harvested forages and stored crops are also used by wildlife as a source of winter feed (Schneidmiller 1988).

While the exact forage demand will vary by type and age of animal, population estimates of wild and domestic herbivores can be viewed as an indication of forage demand. The total number of cattle and calves for dairy and beef in 1985 was 105 million. Sheep numbers were 8.4 million and goats were about 1.6 million. The 1982 Census of Agriculture (USDC Bureau of Census 1984) reported approximately 2 million work horses on farms in the United States. Horses are increasingly becoming a recreational animal. Peat et al. (1987) estimated 5 million horses, predominately recreational stock, and the

Table 3.—Resource outputs from western forest ecosystems.

FRES ecosystem	Plant value	Herbage production (pounds per acre)	Large herbivores	Threatened and endangered animal species
Douglas-fir	Timber, forage, browse	50–1,400	Elk, deer, moose, sheep, cattle	Gray wolf Woodland caribou
Ponderosa pine	Timber-framing, millwork, forage, browse	50–1,200	Deer, elk, cattle	New Mexico ridge-nosed rattlesnake
Fir-spruce	Timber	100–900	Elk, deer, moose, mountain goats, bighorn sheep, cattle	Woodland caribou Grizzly bear
Hemlock-Sitka spruce	Timber	0–400	Elk, deer, moose	Columbian white-tailed deer
Western white pine	Timber	0–400	Elk, deer	
Larch	Timber	0–3,000	Elk, deer, moose, cattle	Woodland caribou
Lodgepole pine	Timber, forage, browse	40–2,300	Elk, deer, moose	
Redwood	Timber		Elk, deer	
Western hardwoods	Timber-paper, landscaping	1,400–2,000 500–4,000 (Aspen)	Deer, elk, cattle, sheep	California condor Columbian white-tailed deer

1985 United Nations Production yearbook (Food and Agriculture Organization 1986) reported 10.6 million horses in the United States. Numbers of white-tailed and mule deer are estimated to be over 16 million, pronghorn antelope over 700 thousand, and elk over 460 thousand (Council for Agricultural Science and Technology 1986). Smaller numbers of moose, bison, wild sheep, and mountain goats are also found in the United States (Flather and Hoekstra in press).

Demand for grazed roughages exists in every region of the United States (fig. 4). Large numbers of wild and domestic herbivores are found in the SO, the NO and the NR region. Deer and cattle are the most numerous herbivores in these regions. The NR region has the largest number of sheep, and the SO region, primarily Texas, has large numbers of goats.

Threatened and Endangered Plant and Animal Species

About 25,000 species, subspecies, and varieties of plants are native to the United States. The Center for Plant Conservation estimates that 680 of these plant species will be extinct in the United States by the year 2000 (Center for Plant Conservation 1988). Under the Endangered Species Act of 1973, federal agencies must ensure that their management actions will not jeopardize the existence of a threatened or endangered plant or animal species. As of July 1988, 185 plant species officially were classified as threatened (147) or endangered (38) (Appendix C). Threatened and endangered animal species can be found on most forest and rangeland ecosystems (tables 2, 3, and 4).

Although grazing pressure has been a concern, 25 species of the last 28 plant species officially listed as threatened or endangered were recognized because of increased human disturbance, either trampling, collecting, off-road vehicle use, road construction, quarrying, or deforestation. The most significant threat to the future existence of plants such as endangered cacti (fig. 5), however, is amateur and commercial collecting (Wright Fishhook Cactus Recovery Committee 1985). Recovery plans for restoring endangered or threatened plants had been approved for 70 plants as of July 1988 (USDI Fish and Wildlife Service 1988).

Wildlife

Wildlife and fish contribute to the functioning of ecosystems in roles such as pollination, seed dispersal and germination, nutrient cycling, and herbivory (Flather and Hoekstra in press). During some part of the year, rangeland ecosystems are associated with 84% and 74%, respectively, of the total number of mammal and avian species found in the United States (Flather and Hoekstra in press). Familiar rangeland species include big game such as pronghorn antelope, small game such as jackrabbit and sage grouse, nongame such as horned lark. Species mobility, public ownership, and state and federal authority for management contribute to the complexity of wildlife and fish management and this complexity increases the importance of cooperation among the public and the managing agencies (Flather and Hoekstra in press).

Forest and rangelands provide food, cover, and water for wildlife (tables 2, 3, and 4) and changes either in the quantity or quality of habitat affect wildlife populations. Wildlife, if associated with specific habitats, are sensitive to changes in those ecosystems, as seen in the declining numbers of the long-billed curlew and the

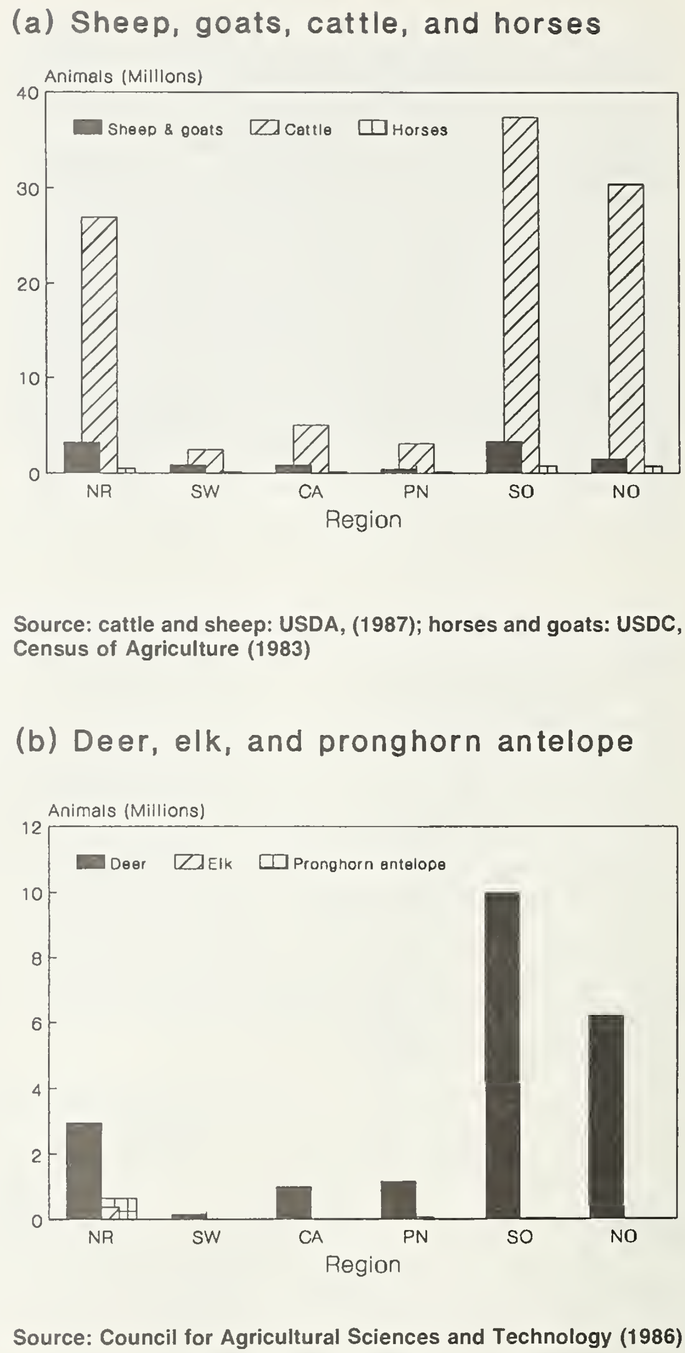


Figure 4.—Number of large herbivores by assessment regions.

Table 4.—Resource outputs from eastern forest ecosystems.

FRES ecosystem	Plant value	Herbage production (pounds per acre)	Large herbivores	Threatened and endangered animal species
White-red-jack pine	Timber	0–400	Deer, moose	Eastern timber wolf Kirtland's warbler
Spruce-fir	Timber	0–800	Deer, moose	Eastern timber wolf Woodland caribou
Maple-beech-birch	Timber	0–800	Deer, moose	Eastern timber wolf
Aspen-birch	Timber	0–400	Deer, moose, cattle	Eastern timber wolf
Oak-pine	Timber, acorns	50–500	Deer, cattle	Eastern cougar
Oak-hickory	Timber, acorns	200–3,000	Cattle, deer	Red wolf Northern flying squirrel
Loblolly-shortleaf pine	Timber, forage, browse	0–1,800	Deer, cattle	Red-cockaded woodpecker
Longleaf-slash pine	Pulp, paper, forage, browse	120–2,600	Deer, cattle	Red-cockaded woodpecker Florida panther
Oak-gum-cypress	Acorns, timber, forage, browse	0–2,000	Deer	Key deer Ivory-billed woodpecker Bachman's warbler Red wolf
Elm-ash-cottonwood	Forage	0–800	Deer, cattle	Eastern timber wolf

reduced area of shortgrass prairie (USDI Fish and Wildlife Service 1982). Lakes and ponds scattered across rangelands, especially in the Great Plains, are important nesting and wintering areas for waterfowl, and intensification of land use, either by grazing or agriculture, can degrade these waterfowl habitats. Two critical issues with respect to wildlife habitat on rangelands include the reduction of area and fragmentation of grassland habitats in the East, and the degradation of riparian habitats in the arid West (Flather and Hoekstra in press).

Wild Horses and Burros

The passage of the Wild Free-Roaming Horses and Burros Act of 1971 delegated authority and responsibility to the Secretaries of Interior and Agriculture for the protection, management, and control of wild free-roaming horses and burros on lands administered by the Bureau of Land Management (BLM) and the Forest Service. Only those public lands are considered in this Act. Wild horses and burros can be found in the many western ecosystems (table 2). Although the greatest number occurs in Nevada, wild horses are also found in California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, and Wyoming. The largest numbers of feral burros occur in Nevada, California, Utah, and Arizona but they are also found in Idaho, New Mexico, and Oregon. Current estimates indicate that the appropriate management levels for FS and BLM-administered lands is under 28,300 wild horses and 3,500 burros. In 1988, over 39,000 feral horses and 5,000 burros were found on FS and BLM-administered lands (USDA Forest Service and USDI Bureau of Land Management 1989). Since 1972, 81,000 animals have been placed through the federal adoption program.

Exotic Animals

The importation of exotic animals, either purposely or accidentally, has a long history in the United States. Some introductions, such as the ring-necked pheasant and the chukar, are considered beneficial, whereas other introductions, such as the Norway rat, are considered detrimental. Since the early 1900s, the number and type

Figure 5.—San Raphael cactus (*Pediocactus despainii*), an endangered cacti, is found in Utah (photo courtesy of Dr.—Kenneth Heil, San Juan College).

of exotic herbivores have continually increased (Doughty 1983). Whereas ranchers originally introduced these animals as attractions, big game ranching has expanded into meat production, live animal sales to zoos or other game ranches, hunting opportunities, and recreational experiences for tourists such as viewing parks. Numbers of some species are now greater in the United States than in their country of origin, and interest in breeding these animals on ranches for zoos has increased (U.S. Congress, Office of Technology Assessment 1986a). Exotic animals are found in large numbers in Texas, but also occur in other states. Exotic animals have been harvested in 22 states (Temple 1982 as cited by White 1987) and membership of the Exotic Wildlife Association in 1985 was 192 members in 18 states (Nicholl 1985, personal communication cited in White 1987).

Water

All range and forest lands function as watersheds that drain into either aquifers or aboveground water storage for agricultural, industrial, municipal, recreational, and navigational uses. High-elevation watersheds are primary water-producing areas in both eastern and western United States. Low-elevation watersheds, used primarily for livestock grazing, contribute little to water quantity, but are important in terms of water quality (Tiedemann et al. 1987). Water management policy has traditionally assumed that the supply of water is a fixed constant (Conservation Foundation 1987). Climate, one of the natural determinants of water quantity, is a dynamic process. Improved analyses of the historical variabilities in climate and the recently recognized potential impacts of human societies on future climate are causing a new awareness of the dynamics of water production (Waggoner 1988). The future management of forest and rangelands will increasingly focus on water production, storage, and water quality (Dixon 1983, Guldin in press, Smith et al. 1987, U.S. Congress, Office of Technology Assessment 1983).

Riparian zones, significant to wild and domestic herbivores, are also important in maintaining water quality, the fisheries resource, and water-oriented recreation such as fishing, kayaking, white-water rafting, or boating (Flather and Hoekstra in press, Guldin in press, U.S. Congress, Office of Technology Assessment 1983). Riparian habitats are extremely productive systems with interchanges of energy, nutrients, and biotic material between the aquatic systems on their inner boundary and the upland range systems on their outer boundary (Kauffman and Krueger 1984). Riparian habitat deteriorates under overgrazing and may be lost when the land is converted to agricultural use, or the stream is channelized for flood control or is flooded for water storage. Where water development changes the flow velocity or periodicity, riparian zones may increase (Skinner 1986). Vegetation management within the riparian zone requires the consideration of the desired use of the area (Skovlin 1984).

Recreation and Scenery

Recreational opportunities on rangelands include nonmotorized recreation such as hiking, horseback riding, picnicking, and skiing, and motorized recreation such as snowmobiling and use of off-road vehicles. Increasing demand for outdoor recreation places pressure on range and forest ecosystems to supply high quality recreational experiences. The long-term protection of recreation resources and open space is one of the high-priority issues facing state recreation agencies (Cordell in press). Demand for recreation is greatest near population centers. Ranching operations are important in maintaining open space in California (Huntsinger 1988). Improved coordination among public agencies, private groups, and industry is seen as a way to more efficiently provide future recreational experiences, facilities, and services on federal and private lands (Cordell in press).

The demand for horseback riding, a significant recreational use on NFS lands, is projected to almost double by 2040 (Cordell in press). Horse-riding activities are associated with private individuals and their own horses, with large groups from lodges adjacent to NFS lands, and with hunting parties led by outfitters (fig. 6). In terms of grazing use, the number of recreational stock is small compared with permitted livestock. Nonetheless, these recreational stock numbers offer some insight into the significance of this form of recreation. In 1986, over 45,000 Animal Unit Months (AUMs) of free recreational stock use were estimated to have occurred on NFS lands across the western United States (USDA Forest Service 1987b). Over 100,000 horses and burros were involved in this use.

Recreational opportunities on private lands have been developed to varying degrees across the United States. The first organized effort to capture additional income from Texas rangelands occurred in 1941 with the development of the Edwards Plateau Game and Wildlife Management Association (Berger 1973). Since then, the leasing of lands for recreational purposes such as hunting has grown, particularly in Texas (Pope and Stoll 1985, Pope et al. 1984a). Other opportunities developing in the private sector on ranches include hunting, fishing, swimming, horseback riding, hiking, camping, cross-country skiing, snowmobiling, photography, historical and geological tours, and bed and breakfast operations with the opportunity to participate in the working of the ranch (USDA Soil Conservation Service 1987c, Wyoming Farm Bureau 1987). Access to water for recreational fishing or boating is also producing income for private ranches.

Clearly the provision of recreation use in an area and how recreationists perceive their experience is influenced by the management of all range resources. Recreation use can impact the vegetation in a number of ways, such as harvesting of plants, trampling, erosive damage to hillsides, or braiding of roads and trails (Andrews and Nowak 1980, President's Commission on American Outdoors 1986). The degree of impact varies with the kind and intensity of recreational use and with environmental factors such as soils, and topography (Payne et al.

1983, Summer 1986). Many range ecosystems provide recreation along with grazing or timber outputs. A majority of recreationists interviewed in the Pacific Northwest indicated that their use of recreational areas would be altered if management intensity increased or became more apparent (Sanderson et al. 1986). The management of range and forest lands for multiple outputs will require a recognition of the type and quality of recreational experience desired, in combination with the production of other resources.

Minerals

Much of the western United States lies over deposits of valuable minerals, including coal and oil, metallic minerals such as lead and copper, precious metals and gems, and common building materials such as sand and gravel. Extracting these minerals is a major component of national, state and local economies. The western states of Texas, Oklahoma, California, New Mexico, Wyoming, together with Louisiana and West Virginia contributed more than 75% of the $188 billion in value added by mining in 1982 (USDA Forest Service RPA Staff in press). Future projections suggest increased domestic production of metallic minerals and increased exploration for and production of domestic energy sources (USDA Forest Service RPA Staff in press). Extensive areas in western United States have been revegetated following mining (fig. 7) and measures will have to be taken to ensure that future mineral extraction is compatible with other uses and that environmental quality is maintained (USDA Forest Service RPA Staff in press).

FOREST AND RANGELAND

Ownership

The Nation's forest and rangeland base is managed by both federal and nonfederal ownerships. Private individuals and state and local governments comprise the nonfederal ownerships, and manage 67% of the total forest and rangeland base. The remaining 33% is under federal management (Bones in press). When rangeland alone is considered, about 64% is in nonfederal ownership. For forest land, nearly 71% is in nonfederal ownership. Land ownership patterns of forest and rangeland vary by region (table 5). Large federal holdings are found in many western states and federal statutes such as the Multiple-Use Sustained Yield Act of 1960, the Wilderness Act of 1964, the National Environmental Policy Act of 1969, the Wild Free-roaming Horse and Burro Act of 1971, the Federal Land Policy and Management Act of 1976, and the National Forest Management Act of 1976 provide strong guidelines for the management of federal lands. The main emphasis resulting from this legislation is the management for multiple resources on federal lands. Private rangelands are managed by the people who own them. The management of nonfederal rangelands is affected by federal statues such as the

Figure 6.—Pack horses on rangelands (photo courtesy of Pat Aguilar, USDA Forest Service).

Figure 7.—Wheatgrass contours on reclaimed mineland in New Mexico (photo by Earl Aldon, USDA Forest Service)

"sodbuster" and "swampbuster" provisions of the Food Security Act of 1985.

Forest and Rangeland Area

Nationally, rangelands represent 34%, or 770 million acres, of the total land base of the United States (Bones in press). Forest lands occupy 32%, whereas pasture and cropland area represents 24% of the Nation's land base. The remaining 10% is classified as human-related land. Thus, over 35% of the Nation's land base has been converted from forest and rangeland for uses such as cropping, roads, industrial areas, and cities.

The present location and area of range and forest land is a function of the historical and current land use within each region of the United States (fig. 8). As the United States was first settled, large areas of eastern deciduous

Table 5.—Area (1,000 acres) of forest and rangeland in federal and nonfederal ownerships.

Region	Regional total	Forest[1]			Rangeland		
		Total	Nonfederal	Federal	Total	Nonfederal	Federal
Rocky Mountains	555,725	142,329	46,760	95,569	413,396	242,485	170,911
Pacific Coast	169,079	101,039	34,036	67,003	68,040	33,212	34,828
Southern	314,850	199,096	179,966	19,130	115,754	115,557	197
Northern	165,987	165,561	152,612	12,949	426	254	172
Alaska	291,780	119,045	101,338	17,707	172,735	102,435	70,300
U.S. total	1,497,421	727,070	514,712	212,358	770,351	493,943	276,408

[1]*Forest land includes transition land.*
Source: Darr (in press) for rangeland; Bones (in press) for forest land.

forest in the NO region were converted to cropland and then to urbanland. As of 1972, over 70% of maple-basswood and beech-maple forests within the maple-beech-birch ecosystem (fig. 2) had been converted to urban, cropland, or pasture (Klopatek et al. 1979). Large areas of productive agricultural land occur on sites formerly occupied by oak-hickory or prairie ecosystems (fig. 2) in Indiana, Illinois, and Iowa. The results of this land conversion is more land in cropland and pasture than in forest in the NO region (fig. 8). Commercial forest land, rangeland, and cropland/pasture are found in the SO region (fig. 8). These forest and range ecosystems provide much of the Nation's timber, along with hunting opportunities for white-tailed deer and wild turkey, and forage for livestock (table 4). Diverse range ecosystems still occur in the southern and western parts of the SO region (fig. 2). The eastern part of the NR region and the western parts of the NO and SO region are referred to as the Great Plains. Over 85% of the prairies dominated by bluestem grass have been converted to pasture and cropland (Klopatek et al. 1979). Agricultural economics and irrigation have fostered the conversion of the plains grassland to cropland (Huszar and Young 1984). The NR region has nearly the same acreage in cropland and pasture as in forest, however, both are overshadowed by rangeland area (fig. 8). In the western United States, the

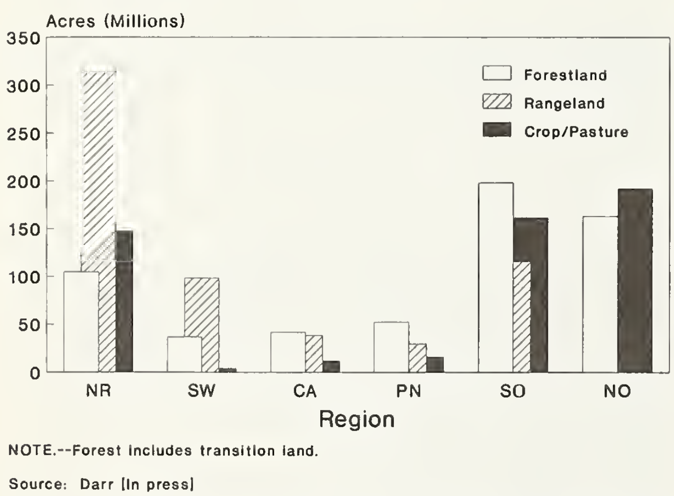


Figure 8.—Forest, rangeland, crop, and pastureland by assessment regions in the United States, 1983.

intermix of large forested areas with rangeland, along with the predominance of federal ownership, provides recreation, water, timber, grazing, and minerals management opportunities (tables 2 and 3). With few exceptions, less than 20% of the natural vegetation in these western regions have been converted to urban or other uses (Klopatek et al. 1979). Forest or rangeland acreages are dominant in the NR, the SW, and the PN (fig. 8). The PN and CA regions have large areas of forest and rangeland that provide much commercial timber, forage, and recreational use (table 3).

Because the impact of humans has had a long history in many parts of the United States, undisturbed examples of these ecosystems are managed as Research Natural Areas (RNA's) on NFS lands (Peterson and Rasmussen 1985). The principal management goals are to preserve a representative array of all significant ecosystems as sources of baseline data, to provide sites for the study of natural processes in undisturbed ecosystems, and to provide gene pool preserves for plant and animal species (Peterson and Rasmussen 1985). Because FRES ecosystems represent groupings of many vegetation types, more than one RNA exists for some forest and range ecosystems. Finer delineations of the oak-hickory ecosystem include the yellow poplar-hemlock type in Alabama and the post oak-black oak type in Ohio (table 6). The broad geographic range of the lodgepole pine ecosystem is represented by RNA's in Oregon, Montana, and Wyoming (table 7). The diversity of wet grassland ecosystems is protected in eastern states such as Delaware, southern states such as Florida and Texas, and western states such as Montana and New Mexico (table 8). While many National Forests have RNA's, some ecosystems are found only on other ownerships, for example the shinnery ecosystem on BLM-administered lands in New Mexico.

The conservation of habitat is the most cost-efficient manner to protect large numbers of plant and animal species and associated ecological processes. This conservation includes, not only the ecological reserves such as Forest Service RNA's, but also management strategies to protect and restore nonreserve habitat (Conservation Foundation 1987). In the United States, some form of protection exist on nearly 7.2% of the land (Conservation Foundation 1987). This estimate includes federal areas such as RNA's as well as state and private reserves (Juday 1988).

Table 6.—Research natural areas in eastern forest ecosystems on federal lands.[1]

FRES type	SAF type	National forest and state
White-red-jack pine	Eastern hemlock	Allegheny, Pennsylvania
		Upper Peninsula EF, Michigan
		George Washington, Virginia
	Red pine	Chippewa, Minnesota
	Eastern white pine	Superior, Minnesota
	Hemlock-yellow birch	Hiawatha, Michigan
Spruce-fir	Red spruce	White Mtn., New Hampshire
	Balsam fir	Superior, Minnesota
Loblolly-shortleaf	Shortleaf pine	Daniel Boone, Kentucky
Oak-pine	Loblolly pine-hardwood	Mississippi, Mississippi
Oak-hickory	Yellow poplar-hemlock	William Bankhead, Alabama
	White-black-northern red oak	Talladega, Alabama
		Ouachita, Arkansas
		Pisgah, North Carolina
	Post oak-black oak	Wayne Hoosier, Ohio
	Chestnut oak	George Washington, Virginia
	Northern red oak	Chequamegon, Wisconsin
Oak-gum-cypress	Sweet bay-swamp tupelo -red maple	Osceola, Florida
	Overcup oak-water hickory	Mississippi, Mississippi
	Baldcypress-water tupelo	Kisatchie, Louisiana
	Sweetgum-willow oak	Francis Marion, S. Carolina
	Water-swamp tupelo	Francis Marion, S. Carolina
Elm-ash-cottonwood	Sugarberry-American elm -green ash	Mississippi, Mississippi
Maple-beech-birch	Sugar maple	Upper Peninsular EF, Michigan
		McCormick EF, Michigan
		Superior, Minnesota
	Beech-sugar maple	Wayne Hoosier, Indiana
	Sugar maple-beech-yellow birch	Pisgah, North Carolina
Aspen-birch	Paper birch	Chippewa, Minnesota

[1]*The Society of American Foresters (SAF) type with the most acres was used to classify the RNA. EF is experimental forest located on a national forest.*

Sources: Franklin et al. (1972a, 1972b); National Science Foundation, Federal Committee on Ecological Reserves (1977); Peterson and Rasmussen (1985); Shanklin (1960).

Land Grazed by Wild and Domestic Herbivores

Grazing is a natural process in most ecosystems. Before European settlement, North American ecosystems were grazed by large numbers of wild herbivores, such as antelope, bison, deer, and elk. Climax vegetation evolved with a complex set of relations between plants, animals, and fire. Since settlement, wild grazers and browsers have declined concurrent with the rise of domestic grazers and browsers (Joyce and Skold 1988, Wagner 1978). Early settlers and those who followed were a new ecological force that realigned the grazing influences already present. Wild grazers were replaced by increasing numbers of domestic grazers, and wild browsers by domestic browsers (Stoddart et al. 1975). Recognized as one of the important resources of rangelands, wildlife and their habitats have increased through recent multiple-use management (Committee on Impacts of Emerging Agricultural Trends on Fish and Wildlife Habitat 1982).

Assessing the land currently grazed by wild and domestic herbivores is a complicated process, hindered by the lack of appropriate data. Not all rangeland or forest land is grazed by large herbivores. Steep slopes, rocky outcrops, highly erosive sites, and flooded areas are unsuitable for grazing. Livestock grazing is prohibited on some ecological preserves and areas under special management. Islands of forest or rangeland may be surrounded by inhospitable environments, making their grazing use by wildlife inaccessible. The widespread distribution of large herbivores across the United States indicates a similar wide distribution of grazinglands (figs. 4 and 8). National statistics for the area grazed by livestock are available for forest and pasture on nonfederal lands and some federal lands. These statistics provide a lower limit of the amount of land grazed by large herbivores.

Nationally, over 16%, or 74.7 million acres, of nonfederal forest land was grazed by livestock in 1982. The percentage of nonfederal forest land grazed in western

Table 7.—Research natural areas in western forest ecosystems on federal lands.[1]

FRES type	SAF type	National forest and state
Douglas-fir	Interior Douglas-fir	Pike, Colorado
		Boise, Idaho
		Salmon, Idaho
		Coconino, Arizona
		Lolo, Montana
	Douglas-fir—hemlock	Willamette, Oregon
		Mount Hood, Oregon
		Mount Baker, Washington
		Gifford Pinchot, Washington
	Port Orford-cedar	Siskiyou, Oregon
Ponderosa pine	Interior ponderosa pine	San Juan, Colorado
		Black Hills, South Dakota
		Santa Fe, New Mexico
		Coconino, Arizona
		Wenatchee, Washington
		Winema, Oregon
		Malheur, Oregon
		Deschutes, Oregon
		Coronado, Arizona
		Fort Valley EF, Arizona
		Ochoco, Oregon
		Lassen, California
		Shasta Trinity, California
		Boise, Idaho
		Custer, Montana
	Ponderosa—sugar pine-Douglas-fir	Rogue River, Oregon
	Pacific ponderosa pine-Douglas-fir	Rogue River, Oregon
	Jeffrey pine	Inyo, California
	Western juniper	Modoc, California
	Arizona cypress	Coconino, Arizona
		Coronado, Arizona
Western white pine	Western white pine	Kaniksu, Idaho
		Flathead, Montana
Fir-spruce	Blue spruce	Uncompahgre, Colorado
	Engelmann spruce-subalpine fir	Gunnison, Colorado
		Pike, Colorado
		Medicine Bow, Wyoming
		Cococino, Arizona
		Colville, Washington
		Willamette, Oregon
		Kaniksu, Idaho
		Manti-Lasal, Utah
	Bristlecone pine	Arapaho, Colorado
	Mountain hemlock	Gifford Pinchot, Washington
		Williamette, Oregon
	Grand fir	Mount Hood, Oregon
		Umatilla, Washington
Hemlock-Sitka spruce	Western hemlock	Tongass, Alaska
		Mount Baker, Washington
		Siuslaw, Oregon
		Olympic, Washington
	Hemlock-Sitka spruce	Tongass, Alaska
		Siuslaw, Oregon
	Western red cedar	St. Joe, Idaho
	Coastal true fir-hemlock	Mount Hood, Oregon
		Mount Rainier, Washington
		Gifford Pinchot, Washington
		Williamette, Oregon
	Western red cedar-western hemlock	Mount Baker, Washington
		Tongass, Alaska

Table 7.—Continued

FRES type	SAF type	National forest and state
Larch	Larch—Douglas-fir	Coer D'Alene, Idaho Lolo, Montana
Lodgepole pine	Lodgepole pine	Bighorn, Wyoming Wallowa-Whitman, Oregon Beaverhead, Montana
Redwood	Redwood	Siskiyou, Oregon Redwood EF, California
Western hardwoods	Oak-diggerpine	San Joaquin Experiment Range, California
	Aspen	Apache, Arizona Caribou, Idaho Wasatch, Utah
	Canyon live oak	Angeles, California
	Cottonwood-willow	Wasatch, Utah
	Interior live oak	Coronado, Arizona

[1] *The Society of American Foresters (SAF) type with the most acres was used to classify the RNA. EF is experimental forest located on a national forest.*

Sources: Franklin et al. (1972a, 1972b); National Science Foundation, Federal Committee on Ecological Reserves (1977); Peterson and Rasmussen (1985); Shanklin (1960).

regions, 72% RM and 33% PC, was much higher than in the NO (6%) and SO (13%) regions (USDA Soil Conservation Service 1987a). The limited amount of nonfederal forest land in the western regions tends to focus resource use on these lands. Much of the forest land in the SO region is used to produce timber and commonly is not managed for grazing, although opportunities for grazing livestock as a silvicultural tool are receiving closer examination (Doescher et al. 1987, Krueger 1987, Pearson 1987). The importance of pasture as a roughage source is evidenced by the extent of grazed pastures. More than 74% of all pasture in the United States was grazed in 1982 (USDA Soil Conservation Service 1987a). No estimates of the percentage of rangeland grazed were available for nonfederal land.

Not all land within the NFS allotments can be grazed. Only 49.6 million acres out of 99.8 million acres are suitable for grazing (USDA Forest Service 1988c). Suitable acres are those acres that can be grazed without sustaining damage to the range resource. Additional acres outside of NFS allotments are suitable for grazing, but no inventory estimates of these acres are available.

No estimate of suitable lands on BLM-administered lands is available. Thus, for this assessment, the acreage estimate for grazed BLM-administered lands incorporates all acres within BLM allotments, over 171 million acres (tables 13 and 14 in USDI Bureau of Land Management 1987). An additional 51 million acres are grazed by livestock on other federal, state, and local agency lands in the western regions, providing over 7.1 million AUMs (Bartlett et al. 1983).

Unfortunately, the available information is insufficient to precisely determine acres grazed by large herbivores in the United States. No acreage information is available to estimate wild herbivore grazing nationally, or livestock grazing on rangelands. If it is assumed that all nonfederal rangeland is grazed, and the above acreage estimates represent the minimum federal land grazed, then over 841 million acres of forest and rangeland are grazed by livestock. This represents 70% of the forest and rangeland base, or 44% of the total land base (excluding Alaska). Cropland and pasture provide a significant amount of forage also but are not included here.

RANGE VEGETATION

Vegetation on range and forest land is a function of climate, fauna, and soils. The management of vegetation affects the total production and composition of plant species which in turn affects the mix of range outputs. The vegetation within some forest and range ecosystems has been altered by overgrazing, disruption of the natural fire cycle, invasion of exotic plant or animal species, alteration of the flow regime from the diversion of water, disturbance from mining, and recreational use.

Range Condition and Ecological Status

Traditionally, the term "range condition" has been used as a measure of the health of the range ecosystem. Range condition has been defined as the extent of departure from the climax vegetation of a site (Stoddart et al. 1975). Early measurements involved a comparison of species present with species of the climax community. A large departure implied poor condition. This rating was based on the susceptibility of the plant species to grazing, and by this definition, a direct cause and effect relation was assumed between livestock overgrazing and the status of vegetation in a deteriorated range. The concept of range condition was difficult to apply to forested

Table 8.—Research natural areas in range ecosystems on federal lands.[1]

Ecosystem	National forest and state
Sagebrush	Snoqualmie, Washington Beaverhead, Montana
Desert shrub	Gila, New Mexico Tonto, Arizona Desert Experiment Range, Utah
Shinnery	Roswell District, BLM, New Mexico
Texas savanna	Laquna Atascosa NWR, Texas
Southwestern shrubsteppe	Bosque del Apache NWR, New Mexico
Chapparral-mountain shrub	Okanogan, Washington Mendocino, California Sierra, California
Pinyon-juniper	Inyo, California Toiyabe, Nevada
Mountain grasslands	Umatilla, Washington
Mountain meadows	Gifford Pinchot, Washington
Plains grasslands	Commache Grasslands, Colorado Custer, North Dakota
Prairie	Nebraska, Nebraska
Desert grasslands	Coronado, Arizona
Wet grasslands	Bombay Hook NWR, Delaware Loxahatchee NWR, Florida Brazoria NWR, Texas Bosque del Apache NWR, New Mexico Lolo, Montana
Annual grasslands	San Joaquin Experiment Range, California
Alpine	Inyo, California

[1] *The type with the most acres was used to classify the RNA. SAF types were not available for range ecosystems. When no RNAs existed for an ecosystem on National Forest System lands, sites managed by other federal agencies were given. NWR is National Wildlife Refuge administered by USDI Fish and Wildlife Service. BLM is Bureau of Land Management.*

Sources: Franklin et al. (1972a, 1972b); National Science Foundation, Federal Committee on Ecological Reserves (1977); Peterson and Rasmussen (1985); Shanklin (1960).

ecosystems, and did not address the impacts on vegetation of other uses of rangeland and forest ecosystems. In addition, the Range Inventory Standardization Committee (1983) pointed out that most vegetation and its physical environment has been disturbed by past use such that the potential natural community (PNC) of the site differs from the original pristine climax plant community.

Two concepts are important in the assessment of forest and rangelands: (1) the maintenance of the long-term productive potential of the site; and (2) the present level of production relative to the potential for a specific use, such as livestock grazing or wildlife habitat (Range Inventory Standardization Committee 1983). The Range Inventory Standardization Committee proposed that ecological status, and a resource value rating be used to assess these two concepts. Ecological status is use-independent whereas a resource value rating is the value of the vegetation for a particular use, such as wildlife habitat or domestic grazing.

Ecological status is a measure of the successional stage of the site. Natural disturbances, such as drought, wild fires, grazing by native fauna, and insects are a natural part of the development of any plant community. Once disturbed and if left without further perturbation, the plant community undergoes a change in function and structure to develop a climax community or PNC (Range Inventory Standardization Committee 1983). The stages of the successional path are referred to as early seral, midseral, late seral, and PNC. The resource outputs vary with each stage, thus management decisions may favor one stage over another, because some successional stages are more productive with respect to the desired resource outputs. The difference between climax, as traditionally used, and PNC reflects the conditions existing today where much of the Nation's vegetation has been altered by past use, including species introductions, grazing, cropping, or logging. On some sites, the PNC will be very different from the climax vegetation type (Range Inventory Standardization Committee 1983).

Because the use of ecological status and resource value ratings represent a departure from the traditional inventory measurements, a time lag will exist before resource inventories may incorporate this approach to measuring range vegetation. Therefore, the current status of range condition must be discussed in light of the definitions used in the existing inventories from different federal agencies.

The Soil Conservation Service (SCS) inventories nonfederal rangelands, and defines range condition as:

> . . .the present state of vegetation of a range site in relation to the climax (natural potential) plant community for that site. It is a expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant community for the site (USDA Soil Conservation Service 1976).

The BLM has used different definitions of range condition (Box et al. 1976), but in 1984, BLM reported that future condition estimates would be based on the definitions of ecological status and resource value ratings given above (USDI Bureau of Land Management 1984). Thus, the 1986 figures for range condition reflect ecological site inventory data on about 52% of the BLM-administered lands, plus range condition estimates based on earlier inventories and professional judgment on the remaining lands. The BLM describes range condition on their lands as similarity with the PNC: excellent = 76-100% similarity, good = 51-75%, fair = 26-50%, and poor = 0-25% (USDI Bureau of Land Management 1987).

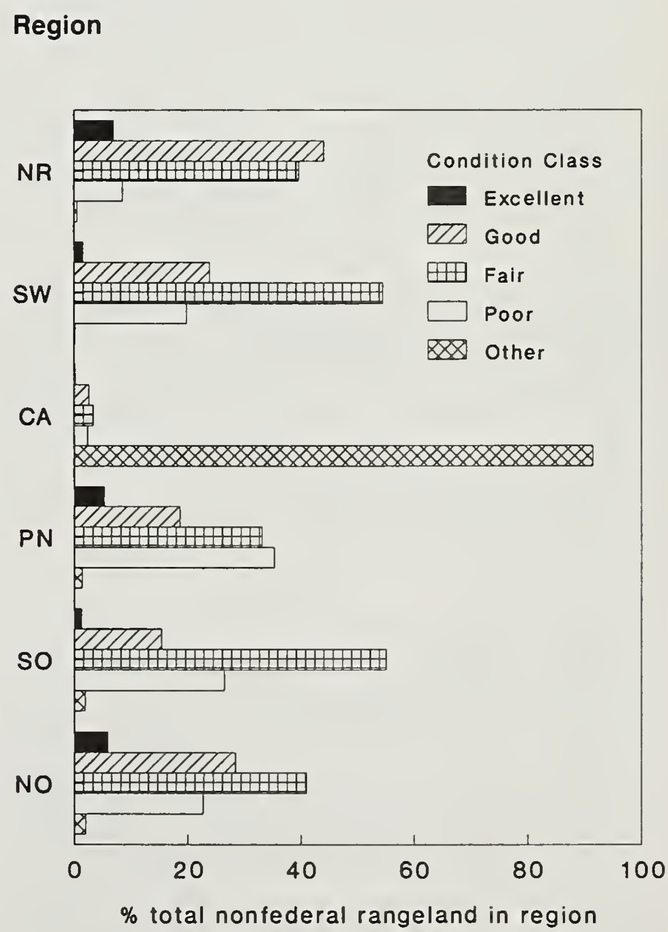
The FS uses ecological status to describe rangeland and forest ecosystems on NFS lands (USDA Forest Service Service Range Management Staff 1986). Ecological status is rated by one of the following categories: PNC, late-seral, midseral, and early-seral stages. These categories are not equivalent to the range condition categories of excellent, good, fair, and poor. Ecological status relates the vegetation to the potential vegetation, not the usefulness of the vegetation to a particular use such as grazing. The usefulness of the vegetation for grazing is assessed by the resource value rating for livestock forage. A satisfactory livestock forage rating is defined as follows: adequate protection for soil, acceptable levels of forage species composition and production or acceptable trend in composition and production for the intended use.

Range condition establishes the current status of the vegetation, and the term "trend" has been used to assess the direction of change of the current community with respect to PNC. Again, these definitions vary by resource inventory. The SCS defines trend as the direction of change in range condition, and measures apparent trend through species composition changes, abundance of seedlings and young plants, plant residues, plant vigor, and the condition of the soil surface (USDA Soil Conservation Service 1976). The FS defines trend in relation to direction of change in ecological status, that is movement toward, away from, or no change with respect to PNC.

Condition of Nonfederal Rangelands

As reported by USDA Soil Conservation Service (1987c), range condition as a percentage of the total nonfederal rangeland base (excluding Alaska) in 1982 was as follows: excellent, 4%; good, 31%; fair, 47%; and poor, 17%. In figure 9, the Other category reflects lands for which range condition ratings have not been assigned such as the annual grasslands of California and areas elsewhere seeded to and dominated by introduced species (USDA Soil Conservation Service 1987c).

The SCS reported that at the national level, the trend in condition of rangelands in the private sector was static on 69% of the land, up on 16%, and down on 15%. The SCS Second Appraisal suggested that, although inventory methods differ considerably, the last three SCS range assessments (1963, 1977, and 1982) indicated that the condition of nonfederal range is improving (USDA Soil Conservation Service 1987c).



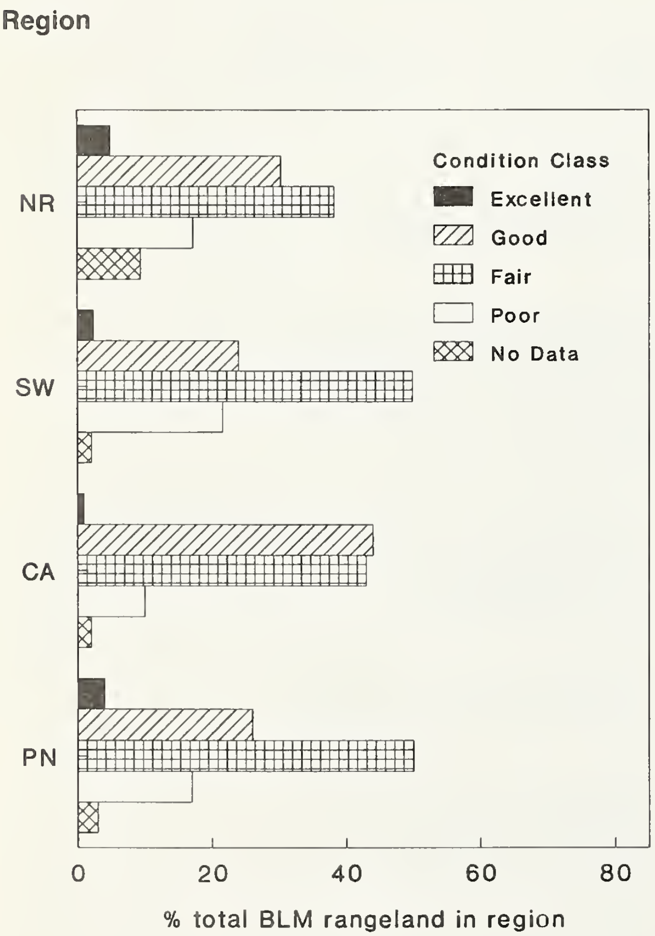
Source: USDA, Soil Conservation Service (1987c)

Figure 9.—Range condition on nonfederal rangelands by assessment regions in the United States.

Condition of Bureau of Land Management-Administered Lands

In 1986, the condition of BLM-administered rangelands at the national level in terms of percentage of total rangeland was: excellent, 4%; good, 30%; fair, 41%; and poor, 18%. These numbers do not include 7% of BLM-administered lands which were unsuitable for grazing or for which data or estimates of condition were unavailable (table 16 in USDI Bureau of Land Management 1987). Alaska was also not included. Condition on BLM-administered lands by assessment regions is shown in figure 10.

Trend information on BLM-administered lands was not available, however data from a number of historical reports were reviewed and compiled into similar categories by Box et al. (1976) and Box (1988). Although these data suggest that condition is improving, Box et al. (1976) stressed that different techniques were used and comparisons are difficult to make. Better inventory data would be valuable (Box 1979).



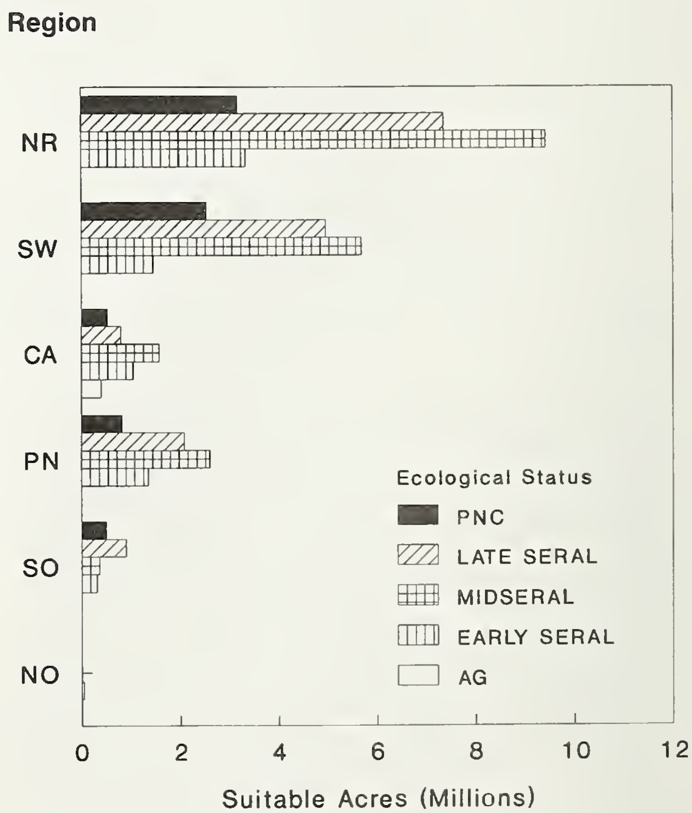
Source: USDI, Bureau of Land Management (1987)

Figure 10.—Range condition on Bureau of Land Management-administered land by assessment regions in the United States.

Condition of National Forest System Lands

A summary of the ecological status of NFS lands nationally indicates that 15% of all NFS lands are at PNC, 31% in late-seral, 38% in midseral, and 15% in early-seral. These numbers do not include annual grasslands (0.8%). The regional distribution of ecological stages varies (fig. 11). The western and southern regions have large amounts of forest land. Timber harvesting and clearcutting place the site in an earlier successional stage, allowing for increased production of herbaceous and shrubby species. Regions with less commercial timber, more grass and shrubland, and a history of grazing tend to have a clumped distribution of acres in the midseral or late-seral stages (fig. 11).

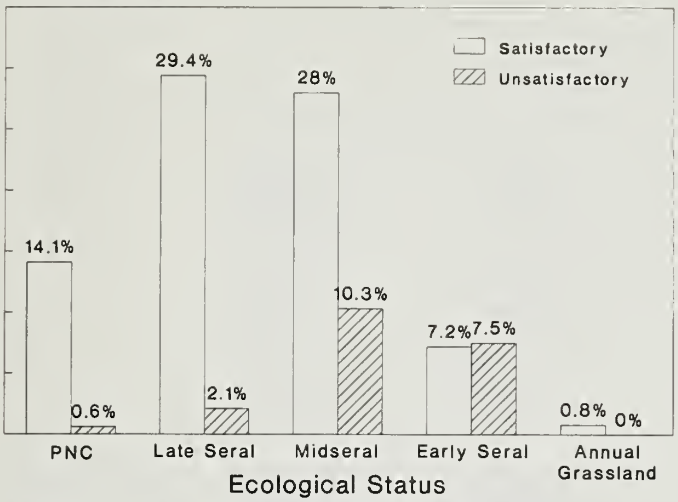
With respect to livestock management, the resource value rating of NFS lands at the national level indicates that 80% are in satisfactory management and 20% are in unsatisfactory management. The early-seral and midseral stages have more lands in unsatisfactory management (fig. 12). In some forest types, early-seral and midseral stages have a more productive herbaceous understory than late-seral or PNC, and thus, these stages would be grazed more often.



NOTE.— AG = annual grasslands.

Source: USDA, Forest Service (1986b)

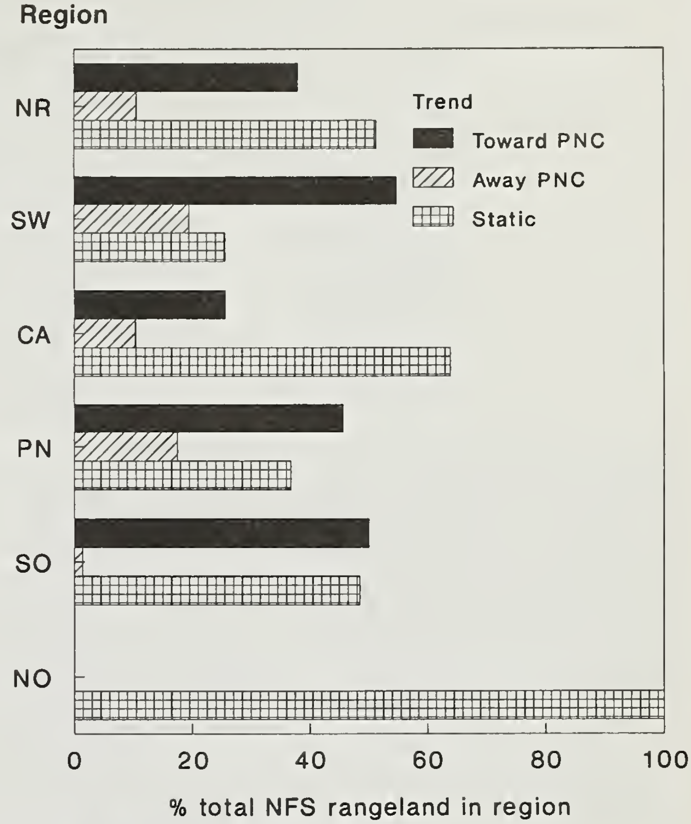
Figure 11.—Ecological status for National Forest System lands by assessment regions in the United States.



Satisfactory • lands with adequate soil protection, forage species composition and production, and acceptable trend in forage species

Source: USDA, Forest Service (1986b)

Figure 12.—Livestock forage value rating within ecological status on National Forest System lands.



Source: USDA, Forest Service (1986b)

Figure 13.—Trend in ecological status on National Forest System lands by assessment regions in the United States.

At the national level, 43% of NFS lands have a static trend in ecological status, 14% are moving away from PNC and 43% are moving toward PNC. The regional numbers follow the national trend; most of the acres are either moving toward PNC or are static (fig. 13). The SW region has the greatest percentage of acres moving away from PNC, a reflection of 400 years of grazing, and severe overgrazing at the turn of the century. Substantial improvements have been made in this region, as indicated by the large percentage of acres moving toward PNC.

Forage Available for Livestock Grazing

The national production of forage is difficult to quantify. As discussed in detail in Chapter 2, forage production is a function of the available land, productivity, and the management of that land. As management can significantly affect the quantity produced, and the implementation of range technology has not been nationally inventoried, a determination of the production of forage is difficult. As reliable livestock inventories are available, however, forage consumed by livestock can be estimated and interpreted as a lower estimate of the forage produced on rangelands and forest lands. The permitted and leased grazing on public lands provides an additional estimate of the supply of forage from these lands.

Permitted or Leased Range Forage

The NFS permitted 10.1 million Animal Unit Months (AUMs) to be grazed in 1985 and 1986 (USDA Forest Service 1986b, 1987b). The RM Region supplied most of these AUMs (table 9). The BLM permitted 13.5 and 12.5 million AUMs[3] to graze in 1985 and 1986, respectively (USDI Bureau of Land Management 1986, 1987). The RM region supplied the majority of these AUMs also (table 9). Comparisons with the AUMs reported from other federal, state, and local agencies (Bartlett et al. 1983) indicate that the NFS and the BLM are the predominate suppliers of forage in the public sector. These other public ownerships supplied slightly more than 7 million AUMs.

Consumption of Grazed Forages in Livestock Production

Beef cattle and sheep represent the largest inventories of livestock that use grazed roughages in the United States. Dairy cattle, goats, horses, and hogs use grazed forages, but their consumption is less than 5% of the total forage consumed annually. Although actual feed consumption figures are not available, USDA estimated that less than 1% of the feed costs for dairy cows is used for pasture (Gee and Madsen 1988). The 1.5 million goats consume about 3.6 million AUMs of grazed forages (Gee

[3]*Animal unit months (AUMs) are defined differently by FS and the BLM. For this report, an animal unit month (AUM) is the forage required to sustain one animal unit for 1 month where one animal unit is considered to be one mature cow or equivalent. For this report, the FS's definition of AUMs was used and BLM AUMS were converted to a unit that is similar to FS AUMs by multiplying the BLM Animal Months (AMs) by 1.2 (USDA Forest Service and USDI Bureau of Land Management 1986).*

Table 9.—Number of permitted AUMs on public lands by region, 1985, 1986.

Region	Forest Service	Bureau of Land Management[1]	Total
1985			
Northern Rocky	5,928,000	8,938,800	14,866,800
Southwest	2,504,000	2,715,600	5,219,600
Rocky Mountains	8,432,000	11,654,400	20,086,400
California	621,000	464,400	1,085,400
Pacific North	745,000	1,222,800	1,967,800
Pacific Coast	1,366,000	1,687,200	3,053,200
Southern	248,000	-------[2]	248,000
Northern	79,000	-------[2]	79,000
Total	10,125,000	13,341,600	23,466,600
1986			
Northern Rocky	5,906,000	8,263,200	14,169,200
Southwest	2,510,000	2,656,800	5,166,800
Rocky Mountains	8,416,000	10,920,000	19,336,000
California	592,000	493,200	1,085,200
Pacific North	748,000	1,122,000	1,870,000
Pacific Coast	1,340,000	1,615,200	2,955,200
Southern	239,000	-------[2]	239,000
Northern	78,000	-------[2]	78,000
Total	10,073,000	12,535,200	22,608,200

[1]*Bureau of Land Management AUMs were converted to a unit that is similar to Forest Service AUMs by multiplying by 1.2 (after USDA Forest Service, and USDI Bureau of Land Management (1986)).*
[2]*No land managed for grazing by BLM in this region.*
Source: USDA Forest Service (1986b, 1987b); USDI Bureau of Land Management (1986, 1987).

and Madsen 1988). This number is small in comparison with the total AUMs consumed by beef cattle and sheep. Although hogs use some grazed roughages, USDA estimated that less than 1% of hog feed costs are for pasture (Gee and Madsen 1988). The estimated 2.0 million horses (fig. 4) also represent a small demand for grazed roughages relative to beef cattle and sheep. Although recreational horses outnumber work horses, the grazed roughages demand from recreational stock is minor as hay and concentrate comprise most of their feed mix (Smith et al. 1986).

Grazed forages consumed by beef cattle and sheep include deeded nonirrigated rangeland and pasture, publicly owned grazing land, deeded irrigated pasture, and crop residues. National estimates of forage consumption by beef cattle and sheep (table 10) are derived from USDA Economic Research Service livestock enterprise budgets (Gee et al. 1986a, 1986b). The structure of these budgets is based on the 1981 national survey conducted by the USDA Statistical Reporting Service in which detailed estimates were made of feed consumption by type of feed and season of use. Nationally, beef cattle consume about 96% of the estimated total grazed forages (table 10). In 1985, total grazed forages for beef cattle were supplied primarily by the private sector; 87% came from deeded nonirrigated grazing land, 6% from public land, 5% from crop residues, and 2% from irrigated pasture. In contrast to this distribution, the supply of grazed forages for sheep was predominately from deeded grazing land (60%) and public land (28%). Consumption of grazed forages in livestock production is examined in detail in Chapters 2 and 3.

INTERNATIONAL RANGE RESOURCE

Rangeland and pasture comprise a major portion of the land base in many of the world's countries (fig. 14). For Africa, Asia, and Oceania, rangeland and permanent pasture is the dominant land cover (Food and Agriculture Organization 1986). The use of these lands is determined by the ecology and economy along with the customs and traditions of individual countries. If the lands are grazed, cultural traditions also influence the type and mix of domestic animals (Rourke 1986, 1987). Livestock numbers are greatest in Asia, a reflection of its large land mass, extensive area of permanent pasture, and additional forage available from cultivated cropland (fig. 15). Africa, with the largest amount of land in permanent pasture of all the world's regions, is second only to Asia in the number of sheep, goats, buffaloes, and camels (Food and Agriculture Organization 1986).

Use of the range resource in the United States is affected by the global use of land, and in particular, the global range resource. The United States interaction with global rangelands occurs through the market place, political systems, and education. As discussed in more detail

Table 10.—Grazed forage consumption (1,000 AUMs and percentage of total) by beef cattle and sheep in the United States, 1985.

Source of grazed forage	Cattle		Sheep		Total	
Deeded Land						
Non-irrigated	359,359	(87.2)	10,742	(56.3)	370,101	(85.8)
Irrigated	8,557	(2.1)	725	(3.8)	9,283	(2.2)
Public land	24,163	(5.9)	5,304	(27.8)	29,467	(6.8)
Crop residue	20,011	(4.8)	2,302	(12.1)	22,312	(5.2)
Total	412,090		19,073		431,163	

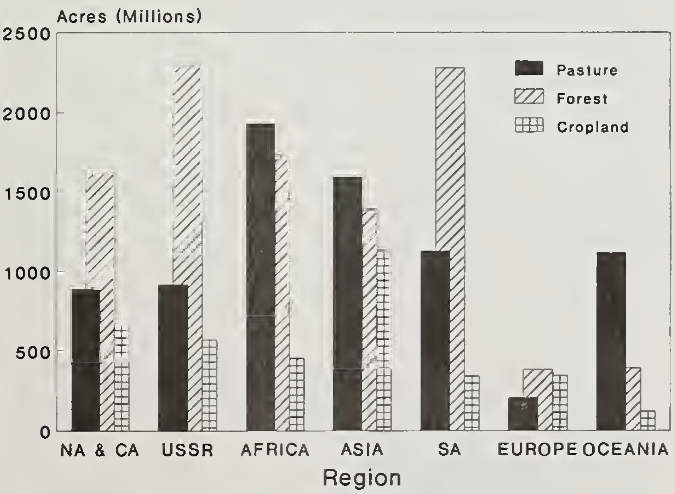
Source: Gee and Madsen (1988).

in Chapter 3, about 8% of the meat consumed in the United States is imported, and 1.5% of the meat produced in the United States is exported (USDA Economic Research Service 1986). Through our political system about $0.9 billion of U.S. foreign aid is allocated for food aid, and over $6 billion for development assistance which includes food loans and grants, and technical assistance projects (Meiman 1988). Although credit for increasing self-sufficiency in food production has been given to university outreach programs and the Green Revolution (Meiman 1988), recent range and livestock programs have been poorly evaluated (Thomas 1987). One reason for poor success has been the inability of development programs to recognize local cultural and ecological systems which may be very different from western traditions and temperate ecosystems (Ellis and Swift 1988). Future development projects will need to understand the cultural and ecological systems before establishing projects.

The Food and Agriculture Organization (1977) concluded that available world food supplies should be sufficient to provide everyone with an adequate diet if the problem of distribution could be solved. In The Global 2000 Report to the President, projections for food and agriculture suggested a continuation in the growing importance of variability in supply (Council of Environmental Quality and USDS 1980). Expansion of agriculture into marginal areas increases the susceptibility of crop production to weather fluctuations, and in the future a larger proportion of the world's food supplies will be dependent on *favorable* (above average) rather than average rainfall and temperature (Council on Environmental Quality and USDS 1980).

The results of a recent United Nations report indicate that desertification is extending in area and intensity world-wide (fig. 16) (UNEP 1984). As of 1984, 35% of the earth's land surface and 20% of the earth's human population were considered to be threatened by encroaching deserts (Marbutt 1984). At least 35% of this total land surface has lost more than 25% of its productivity and is in serious need of reclamation (Karrar 1984, Marbutt 1984).

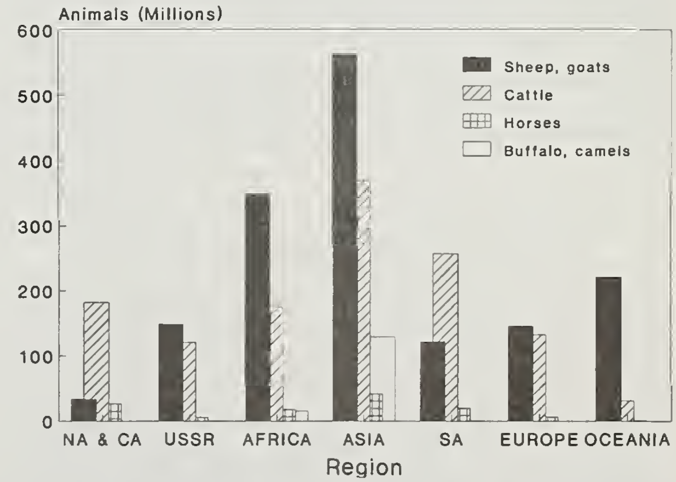
Over 7,600 million acres is at least moderately desertified and half of the world's rangeland is in severe or very severe desert conditions (Marbutt 1984). The proportion is higher (>60%) in developing regions, and



NOTE.--Oceania = Australia, New Zealand, South Pacific Islands. NA, CA, SA = North, Central, South America.

Source: Food and Agriculture Organization (1986)

Figure 14.—Forest, permanent pasture (tame, native, and rangeland), and cropland area of the world, 1984.



NOTE.--Oceania = Australia, New Zealand, South Pacific Islands. NA, CA, SA = North, Central, and South America.

Source: Food and Agriculture Organization (1986)

Figure 15.—Number of sheep, goats, cattle, horses, buffalo, and camels in 1985 by major regions of the world.

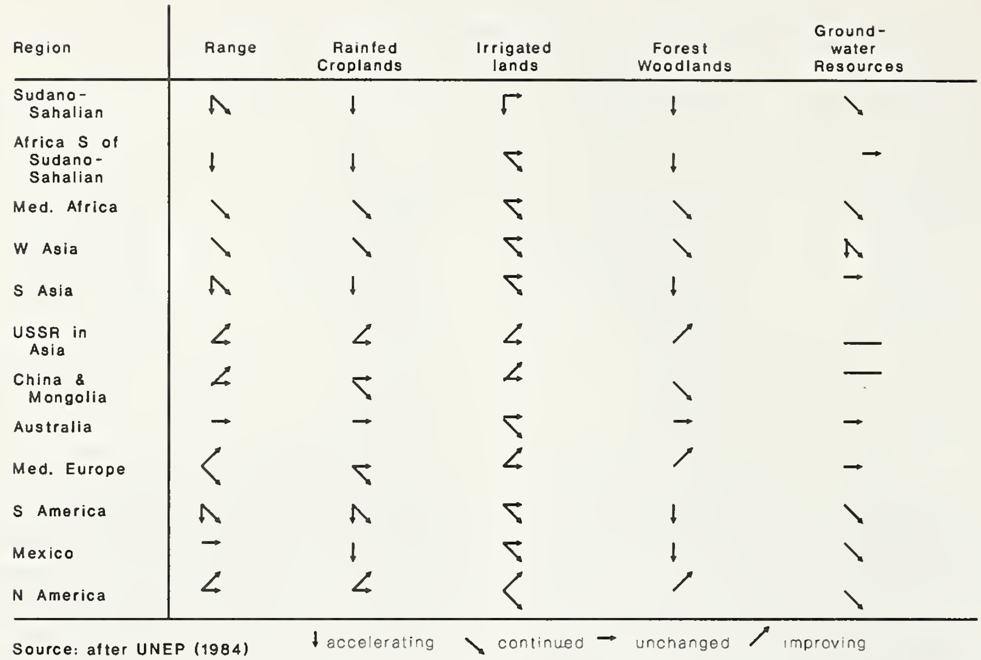


Figure 16.—Regional trends of desertification within land-use and major natural resources.

lower (<40%) in the developed regions such as North America and Australia. Rangeland areas of immediate concern are the interfaces between the semi-arid grazing-lands and the densely-populated rain-fed croplands. Agriculture is encroaching upon grazinglands, restricting livestock and wildlife to smaller areas. Other areas of concern are the interfaces between semi-arid and sub-humid mixed farming areas in hilly tracts, as in Africa south of the Sudano-Sahelian region and in Andean South America. In developed regions, the invasion of woody vegetation of low pastoral value was considered to be the major problem of rangelands (Marbutt 1984). Increased population growth coupled with increasing poverty in many countries has and will continue to put pressure on range vegetation and plant species survival (Lucas and Synge 1981). This pressure comes at a time when research on new or alternative agricultural and industrial crops has increasingly turned to the vast unstudied plant resources of the tropical zones (Plotkin 1988).

SUMMARY

Range and range resources mean many things to many people. Range vegetation is defined as grasses, grass-like plants, forbs, and shrubs. When the plant community is dominated by this type of vegetation, the land is referred to as rangeland. Although rangelands predominate in western United States as natural grasslands, shrublands, savannas, deserts, tundra, alpine, coastal marshes, and wet meadows, rangelands in the eastern United States occur as tallgrass prairie, marshes, or wet meadows. Riparian ecosystems and plant communities dominated by introduced species are also considered rangeland. About 34% or 770 million acres of the total land base in the United States is rangeland.

Range vegetation is the building block for multiple resource outputs from rangelands and forests. Range outputs include native plants for agricultural, reclamation, or landscaping purposes; forage for wild and domestic herbivores; habitats for wildlife, threatened and endangered plants and animals, and wild horses and burros; water; recreation; and minerals.

Range condition is reported by various federal agencies, and in light of the different definitions used in the current inventories, range condition is discussed for each reporting agency. The SCS reported condition as a percentage of the total nonfederal rangeland base in 1982: excellent, 4%; good, 31%; fair, 47%; and poor, 17%. The BLM reported 1986 figures as follows: excellent, 4%; good, 30%; fair, 41%; and poor, 18%. On NFS land, ecological status was reported as follows: 15% at PNC, 31% in late-seral, 38% in mid-seral, and 15% in early-seral. At the national level, 80% of NFS lands are in satisfactory management for livestock.

Forage consumed by livestock can be interpreted as a lower estimate of the forage produced on rangelands and forest lands. The NFS permitted 10.1 million AUMs to be grazed in 1985 and in 1986. The BLM permitted 13.5 and 12.5 million AUMs to be grazed in 1985 and 1986. Other public ownerships supplied less than 8 million AUMs.

Beef cattle and sheep represent the largest inventories of livestock that use grazed roughages in the United States. Dairy cattle, goats, horses, and hogs use grazed forage but their consumption is less than 5% of the total forage consumed annually. Nationally, beef cattle consume 431 million AUMs; 86% comes from deeded nonirrigated grazing land, 7% from public land, 5% from crop residues, and 2% from irrigated pasture. The supply of grazed forage for sheep was different than for cattle in that only 60% came from deeded grazing land and 26% from public land.

CHAPTER 2: FACTORS AFFECTING FORAGE PRODUCTION

INTRODUCTION

Production of Range Resource Outputs

Natural resource outputs, such as timber, forage for wild and domestic herbivores, water, and recreation are produced jointly from forest and rangeland ecosystems. Different management goals yield different mixes of these outputs. The national supply of these resources is a function of efforts in individual enterprises and on public lands. The future supply of these resource outputs is closely associated with their future demand. The future management of forest and rangelands in private and public ownerships will determine the future supply of these outputs.

Quantifying the future supply of these range resource outputs at the national level involves an analysis of factors underlying their production. The future national supply of outputs, such as native plants for harvest or cultivation, is difficult to quantify because the factors affecting demand or supply are local. The future supply of wildlife, wild horses and burros, and livestock is dependent on the future supply of forage. Range vegetation is fundamental in the joint production of many range outputs, including forage. This chapter focuses on quantifying the future supply of forage as a function of rangeland productivity and land availability for grazing. As many factors associated with forage demand influence production, future supply is closely related to future demand. Factors underlying supply (this chapter) and underlying demand (Chapter 3) are used to determine the future forage supply and demand at the national level (Chapter 4). A case study projecting the impact of resource management and land use changes on forage production at the regional level is presented (this chapter) as a potential method to analyze resource interactions in assessments.

Determinants of Forage Supply

Forage, that part of vegetation that is available for consumption by herbivores, is produced on forest land, rangeland, pasture, hayland, cropland (after crop harvest), and cropland used for pasture. Forage is produced on private and public lands. Range vegetation covers the landscape naturally, and range management influences the quality and quantity of the forage component of range vegetation. Forage on forest and rangelands is typically produced with little or no agronomic practices, whereas forage on pasture or haylands may be intensively cultivated, seeded with improved species, irrigated, and fertilized. Where economically feasible, such management practices may be used to enhance forage production on forest and rangelands. Mechanically harvested forages from pasture or haylands are important in providing feed when grazed forages are unavailable.

The production of forage is undertaken with the expectation of some value accruing from the production effort (Tyner and Purcell 1985). Forage is used to produce livestock for meat and other products, wild horses and burros for preservation, and wildlife for recreation or preservation. The value attached to forage differs depending on the output, and the quantity of forage produced depends on the value of the output to the producer. Within a farm or ranch enterprise, forage production will be determined by the demand for livestock or wildlife (Glover and Conner 1988, Tyner and Purcell 1985). Nearly 78% of the forage consumed by livestock is produced from nonirrigated pasture owned by the livestock enterprises and, therefore, is not priced in a forage market (table 10). Thus, decisions to implement management practices to improve forage production will be based on the likely economic return associated with the final output, such as livestock or wildlife.

The amount of forage produced on public lands is set by multiple resource management objectives and public policy. Thus, the quantity produced on public lands will be a function of multiresource management for wild and domestic grazing animals and other resource outputs such as timber, water, recreation, and scenic beauty.

Assessing the forage produced nationally is difficult because forage production is not inventoried. Use, not production, is quantified when forage consumption estimates are derived from livestock inventories (table 10). Further, populations of wild grazing animals are not censused nationally as are livestock, thus deriving an estimate of the forage consumed by wild herbivores is also

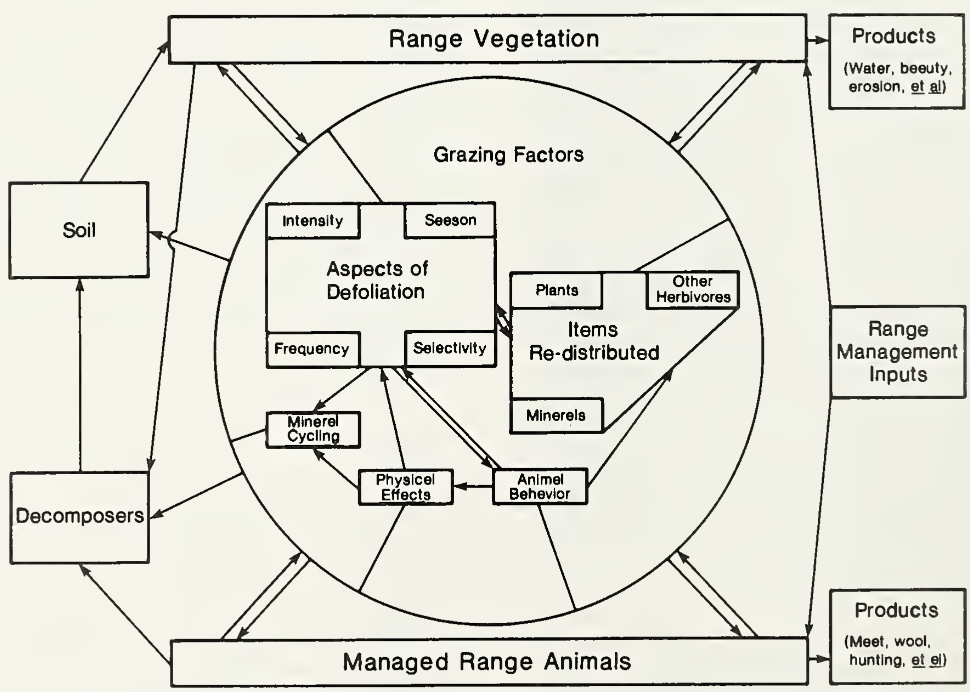
difficult. Forage consumption represents only part of the forage produced on forest and rangelands. Physical inaccessibility may reduce grazing use of vegetation or, like the harvesting of timber on steep slopes, forage production may require additional expenses that make the utilization too expensive for the return. For example, the use of some areas by livestock often requires fencing to keep animals from grazing nearby palatable crops (Tyner and Purcell 1985), or areas may go unused by wild herbivores because of proximity to urban activities.

The national supply of forage is a function of the current and likely future management on forest and rangelands and the current and projected inventory of land available for forage production. Management results are influenced by the ecology of these forest and rangeland ecosystems. Past and current management includes grazing, timber harvesting, mining, cropping and the abandonment of cropland, and species introduction. These uses have and will affect the current production and potential production. Multiresource management requires a consideration of the tradeoffs in resource production. Future management practices, new technology, and eventually biotechnology, offer possibilities to enhance the future productivity of forest and rangelands. The availability of land for forage production is a function of the demand for land for other uses. Conversion of forest and rangeland to uses such as cropland or a non-revertible use such as urbanland decreases the land available for forage production.

Forage production projections will be derived from projections of the likely future technological improvements in forage production and projections of land available for forage production. The present chapter discusses the impact of technology and land availability as they have historically affected the production of forage at regional and national levels.

DYNAMIC NATURE OF ECOSYSTEMS

Range ecosystems are diverse and complex systems involving the flow of energy and the cycling of minerals through primary producers (range vegetation), herbivores (livestock, big game, nongame), and the detrital system (decomposers involved in the breakdown of organic matter) (fig. 17). The diversity of ecosystems across the United States is evident (fig. 2). These ecosystems have evolved to survive erratic precipitation, extreme temperatures, and natural disturbances (such as fire). As ecosystems respond to natural or human-caused disturbances, plant and animal species may change. These shifts in community structure are referred to as succession. The production of certain outputs, such as forage for wild and domestic herbivores, may require that the



Source: after Heady (1975)

Figure 17.—Vegetation influences range animals and animals influence range through a number of interacting factors.

ecosystem be managed for an earlier stage than the Potential Natural Community (PNC). The biotic and abiotic processes within ecosystems induce a spatial heterogeneity across forest and rangelands (Risser et al. 1984) and link site-specific land management activities with the surrounding landscape. The management of spatial and temporal heterogeneity or biodiversity requires an understanding of the spatial and temporal aspects of natural disturbances such as fire, and management such as livestock grazing, timber harvesting, or recreation. Manipulation of these systems and the maintenance of biodiversity requires an understanding of the underlying ecological processes, their response to intensive or extensive management, and the consequences of management in the range and forest landscape.

Climate

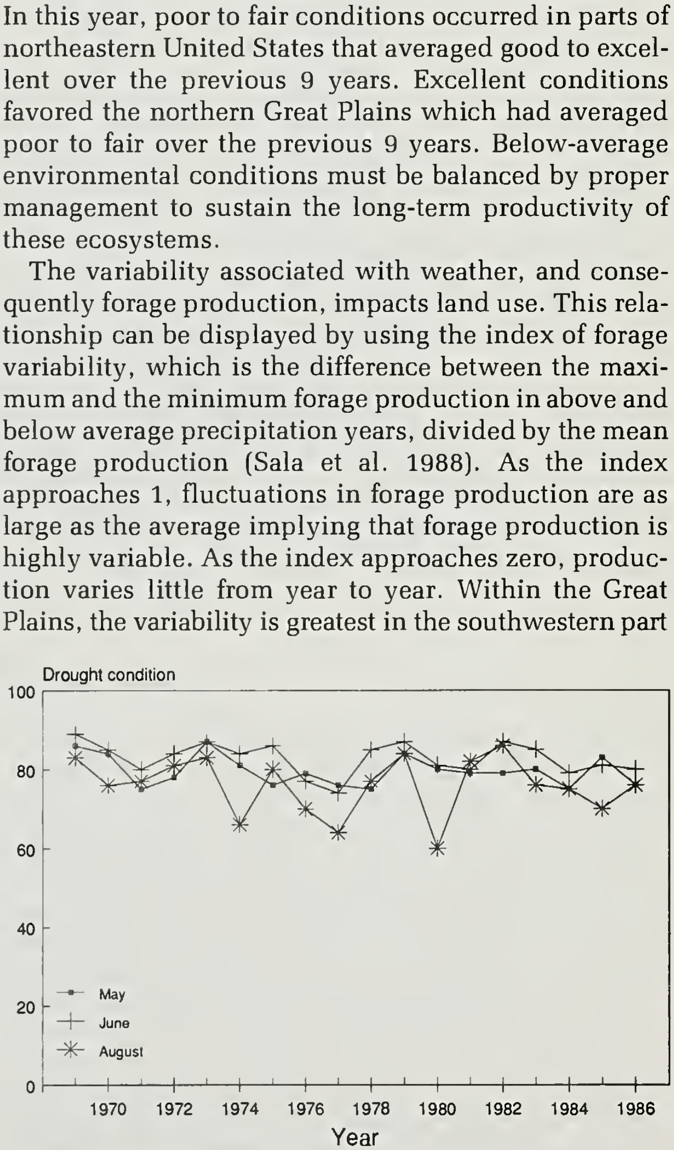
Weather and soil are the primary abiotic factors affecting forage production on forest and rangelands (Eckert and Klebesadel 1985, Herbel and Baltensperger 1985, Marbel et al. 1985, Moore and Lorenz 1985). Whereas the average precipitation of the United States is about 30 inches, annual precipitation is less than 1 inch in parts of the arid West, greater than 60 inches in southern Florida, and nearly 400 inches on some Hawaiian islands (Guldin in press). The eastern United States has an annual average greater than 40 inches, whereas most of the western United States receives less than 20 inches of precipitation annually. These averages suggest that different plants and different adaptations by plants to climate are made across the United States.

Average precipitation is derived from the tabulation of many years of data. Actual values of annual precipitation can range from zero to many times the annual average. The extremes, not the means, are the potentially harmful climatic events (Waggoner 1988). Drier climates are relatively more variable than wet ones, and changes in a drier climate will bring relatively more variation in annual precipitation (Waggoner 1988). Droughts can occur anywhere in the United States, and there is usually an area of drought each year (Trenberth et al. 1988). Western droughts have been numerous in the historical past: 1888-90, 1892-94, 1898-04, 1901, 1910, 1917, 1919, 1924, 1928-34, 1936, 1953-56 (Coupland 1958, U.S. Senate 1936). The more widespread dry years of the 1930's have been referred to as the ''dust bowl years.'' Early records described the frequency of drought to be at least one or two years in every 10 years in western United States (U.S. Senate 1936).

Changes in environmental conditions within a growing season can be observed by using the national index of pasture and rangeland condition (U.S. Department of Agriculture 1987) (fig. 18). Measured on the first of May, June, and August, this national index reflects the seasonal variability in precipitation and temperature from 1969 to 1985. Good environmental conditions early in the year may deteriorate as precipitation decreases and temperature rises toward the end of the growing season, especially evident during August in 1974 and 1980 (fig. 18).

Environmental conditions vary not only year to year but also across the United States (fig. 19). The average 1975-84 pasture and rangeland condition was good to excellent in far western and northern parts of the United States, but conditions averaged only poor to fair in the northcentral and southern parts of the United States (U.S. Department of Agriculture 1987). These spatial patterns contrast with drought conditions in 1986 (fig. 19). In this year, poor to fair conditions occurred in parts of northeastern United States that averaged good to excellent over the previous 9 years. Excellent conditions favored the northern Great Plains which had averaged poor to fair over the previous 9 years. Below-average environmental conditions must be balanced by proper management to sustain the long-term productivity of these ecosystems.

The variability associated with weather, and consequently forage production, impacts land use. This relationship can be displayed by using the index of forage variability, which is the difference between the maximum and the minimum forage production in above and below average precipitation years, divided by the mean forage production (Sala et al. 1988). As the index approaches 1, fluctuations in forage production are as large as the average implying that forage production is highly variable. As the index approaches zero, production varies little from year to year. Within the Great Plains, the variability is greatest in the southwestern part



NOTE.--Numerical equivalent of condition: 80 and over, good to excellent: 65-79, poor to fair; 50-64, very poor; 35-49, severe drought; and under 35, extreme drought.

Source: USDA (1987)

Figure 18.—Average pasture and range drought condition, as measured May 1, June 1, and August 1 in the United States.

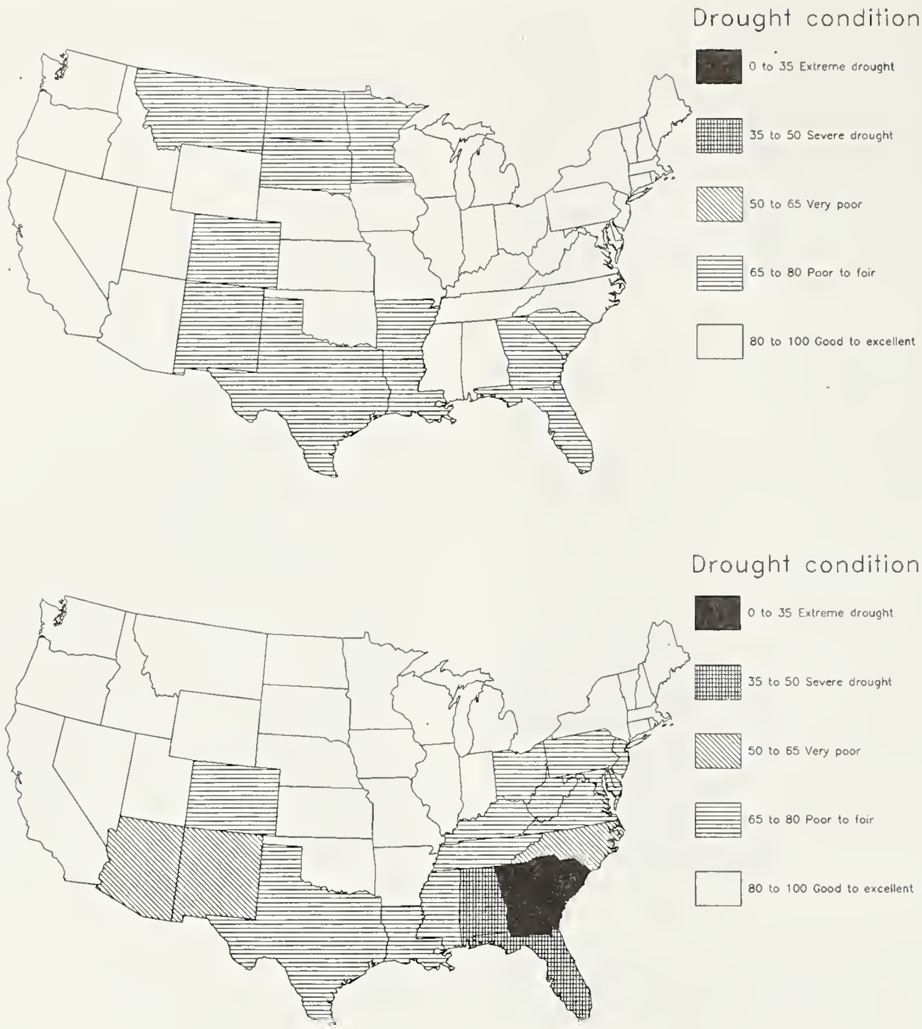
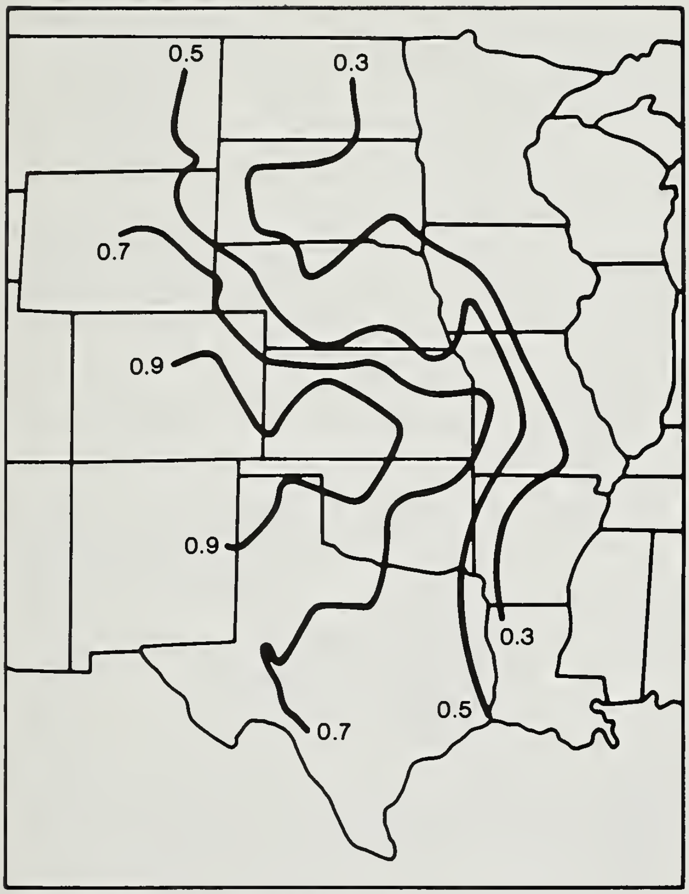


Figure 19.—Pasture and range drought condition, June 1.

of the region, in the corner of the Colorado, New Mexico, Oklahoma, and Texas state boundaries (fig. 20). Variability decreases as one moves further east and north. Annual precipitation also increases in this direction. The shape of the area where variability is higher than 90% coincides with Borchert's (1950) wedge of spring and summer rainfall deficiency, characteristic of major drought years across central United States. Borchert (1950) showed that during drought years, precipitation tended to decrease toward the center of this wedge-shaped area and be near or above normal outside the wedge.

This area of greatest variability in forage production also coincides with the largest acreage enrollment of the most recent government crop set-aside program, the Conservation Reserve Program, and with the largest acreage enrollment of the 1950s government program, the Soil Bank program (Reichenberger 1987). Crop production in the Great Plains is subject to the same environmental variability as forage production. The management of these lands, the government agricultural programs, and the environment interact to influence changes in land use within this region and across the United States.

Although the results are unclear, evidence exists that the average air temperature will rise globally from 1 to 5° C because of past and current greenhouse gas emissions, such as carbon dioxide (U.S. Environmental Protection Agency 1988). These greenhouse gases absorb the earth's infrared radiation and warm the atmosphere. Future concentrations of these greenhouse gases based on forecasts of energy consumption, energy efficiency, and population growth are projected to double by the year 2030 (Mintzer 1987). Stringent energy conservation and efficiency would delay the doubling until 2075 (Mintzer 1987). The implication of this warming on the globe's climate is the focus of general circulation models, however, the resultant changes in local or regional climate are hard to forecast. Changes in climate will involve not only temperature changes, but also annual precipitation amounts and the seasonal distribution of this precipitation. For arid areas, the subtle shift



Source: after Sala and others (1988)

Figure 20.—Variability in forage production across the Great Plains as measured by the forage production index.

in increased variability of precipitation could potentially cause significant shortages in water for plants, animals and humans (Guldin in press, Waggoner 1988). These changes in climate could affect the current distribution of plants and animals, and the possibility exists for these climatic changes to occur more quickly than plants or animals could adapt (U.S. Environmental Protection Agency 1988). These changes imply the loss of plant and animal species, and the movement of plants into new ranges. These vegetation changes will imply shifts in land use, and economies dependent upon natural vegetation, such as rangeland, will be impacted by the potential future changes in climate. The projections for forage in this assessment are based on a future in which the climate follows historical trends. This assumption may not be met if the earth's climate changes rapidly. A number of studies have been initiated by the Forest Service (USDA Forest Service 1988a) and others (Committee on Earth Sciences 1989, Special Committee for the IBGP 1989) to examine the potential impacts of climate change.

Succession and Disturbance

Succession

The response of ecosystems to stress and disturbance is a function of the development and the past management of the ecosystem. Some of the different stresses under which ecosystems evolved include recurrent fire, grazing, no grazing by herbivores, periodic drought, high winds, and periodic flooding. As an ecosystem responds to repeated disturbances, soil, vegetation, and animal communities may follow a recovery path that is similar to the original path of ecosystem development. This response is particularly true if conditions are similar to those that existed when the ecosystem was developing (such as the periodicity of fire), and past use has not greatly altered one or more environmental factors (such as excessive erosion or introduced species). This path has been referred to as succession: the different plant and animal communities along this path are called successional stages (Cattelino et al. 1979, Drury and Nisbet 1973, MacMahon 1981, Odum 1971, Raynal and Bazzaz 1975, Shugart and West 1981). Major natural disturbances, steps in initiating revegetation after a disturbance, and the rate of recovery differ across ecosystems (MacMahon 1981). Different disturbances or stresses may induce an ecosystem to progress along different paths of recovery.

The management of ecosystems for multiple resource outputs requires an understanding of the individual ecosystem response to stress or disturbance. As different vegetation and animal species are present in each of the successional stages, the management for specific resource outputs may require managing for the stage that produces the desired output, and this successional stage may not be the PNC.

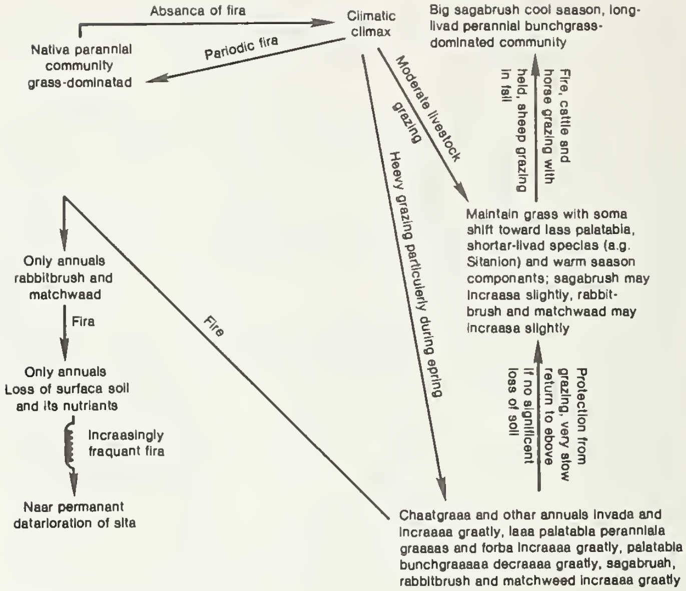
Natural Disturbance

Grazing animals have long been a part of forest and rangelands. Wild and domestic grazing animals influence primary production and other processes in the range ecosystem in a number of ways: defoliation of plants through eating and physical damage, digestive processes and the deposition of waste products, and movements such as bedding and trailing (Heady 1975, Pieper and Heitschmidt 1988). Defoliation from grazing has four aspects: (1) the intensity or degree to which a plant is defoliated, (2) the frequency or number of times a plant is grazed within a growing season, (3) the phenological stage of a plant when grazed, and (4) selectivity or the preference of the plant by the grazer or browser (fig. 17). These grazing influences imply management manipulations possible with grazers: adjust intensity, frequency, and seasonality of grazing, or change to a kind or class of animal with different diet preferences or grazing behavior (Heady 1975). Plant species consumed by cattle may or may not be the same plant species that deer, elk, goats, or sheep consume. Competition between grazing animals occurs when the dietary

overlap is great, little forage is available, or large numbers of animals are grazing the same area. Thus, the impact of the grazing animal will depend on the type or types of animal using an area.

Periodic fire is a part of the natural disturbance regime of North American grasslands (Sims 1988b, Wright and Bailey 1982). Although the presettlement frequency of fire in the Great Plains cannot be determined precisely, Wright and Bailey (1982) concluded that on level to rolling prairie grasslands, the fire frequency may have been every 5 to 10 years. The suppression of fire in the eastern parts of the prairie ecosystem has led to the encroachment of trees and shrubs from the eastern deciduous forests. Periodic fire also reduces competitive advantage of cool-season invaders such as Kentucky bluegrass and smooth brome and improves the palatability and nutritional value of the grazable forage (Sims 1988b).

Management can disrupt a natural disturbance cycle and change the ecology of an ecosystem, as seen in the lowland sagebrush semi-desert ecosystem. When periodically disturbed by fire and in the absence of heavy grazing, this ecosystem moved towards a native perennial grass-dominated community (West 1983). When disturbed by moderate livestock grazing and fire, the community of perennial grasses contain additional less palatable, shorter-lived, species of grass and increased amounts of sagebrush (fig. 21). Heavy grazing pressure reduced the occurrence of perennial grasses, allowing the increase of brush and the invasion by annual grasses, particularly cheatgrass (Young et al. 1987). These annual grasses initiate and complete their growth and the production of many seeds during the short period of spring moisture. During the dry season, these annual grasses provide a fine-textured fuel for wildfires that spread from shrub to shrub (Young et al. 1987). Annual grasses can withstand fires better than the perennial grasses, thus, grazing and increased reoccurring fires favor annual grasses over perennial grasses. A declining spiral of productivity ensues, and annual grasses replace perennial grasses in this ecosystem (West 1983). Removing the grazing animals does not foster the return of the historical successional dynamics once annual grasses dominate (fig. 21).



Source: after West (1983)

Figure 21.—Major pathways of succession in plant communities on lowland sagebrush semi-desert sites.

Forest Succession

In forest ecosystems, the first vegetation to appear after timber harvest is grasses and forbs, followed by shrubs (Thomas 1979). This transitory range offers forage for wild and domestic herbivores. The length of these early successional stages varies by the physical and biotic characteristics of the site. In southern forests, the grass and forb stage lasts less than 10 years. In western United States, weather or soil factors may extend these stages to 20 to 40 years. Eventually, trees begin to colonize this previously forested site and reduce sunlight reaching the forest floor. Management activities can shift understory vegetation to an earlier or later successional stage depending on the current status (fig. 22). Shrub control with herbicides can facilitate tree growth by reducing shrub competition, thus encouraging successional processes in forest ecosystems. Grazing in the grass-forb stage retards shrub and tree growth, thus retarding succession. The many types of herbivores will differentially impact species composition and succession (fig. 22). The timing of management applications, such as fertilization or controlled burn, influences the direction of change also (fig. 22). Timber management practices, such as thinning, open up the forest canopy, allowing sunlight to reach the forest floor, and increase grass and forb production.

On commercial forestlands, the biological environment is manipulated to intensively grow trees. Where environmental factors are not limiting vegetation growth, a possibility exists to maximize multiresource production on these sites. The introduction of pasture grasses under timber plantations and irregular spacing of trees can enhance the production of understory forage on these commercial forestlands (Lewis 1984). The introduction of grazers to reduce grass, forb, and shrub competition with trees can increase the diameter growth of small trees 8-14% (Mosher 1984). The multiple use management of timber plantations can have benefits in terms of increased profit, biological control of competing vegetation, and recreational benefits from wildlife (Pearson and Cutshall 1984).

Changes in the Resource Base

The historical and current management of forest and rangeland has changed the composition of plant and animal species in many ecosystems. Although livestock grazing has received much focus as a primary change agent, other uses have also affected forest and rangelands. All land in the United States now in cropland or

Management action	Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
Shrub control:						
• Herbicides	▶	▶	▶	◀	◀	◀
• Mechanical control	◀	◀	NA	◀	◀	◀
Controlled burn:						
• Cold burn	◀	◀	▶	▶	◀	◀
• Hot burn	◀	◀	◀	◀	◀	◀
Fertilization	◀	▶	▶	▶	▶	O
Grazing and browsing (moderate rates):						
• Cattle and sheep	◀	▶	O	O	◀	◀
• Goats	O	◀	O	O	◀	◀
• Deer and elk	◀	▶	O	O	◀	◀
Planting:						
• Trees	▶	▶	NA	NA	▶	▶
• Shrubs	▶	◀	NA	NA	NA	NA
• Grasses-forbs	▶	◀	NA	▶	▶	O
Regeneration cut:						
• Clearcut	NA	NA	NA	◀	◀	◀
• Shelterwood	NA	NA	NA	▶	◀	◀
• Seed tree	NA	NA	NA	◀	◀	◀
Salvage	NA	NA	◀	◀	◀	◀
Thinning (including single tree selection harvest)	NA	▶	▶	▶	▶	O

▶ advances succession
◀ retards succession
O no affect on succession
NA not applicable

Successional stage condition

Source: after Thomas (1979)

Figure 22.—Anticipated changes in successional stage resultant from management activities on forest land.

urban use was at one time forest or rangeland (fig. 8). Presettlement vegetation was probably near or at climax, with an occasional disturbance by natural catastrophe causing the vegetation to return to an early stage and succession (Wagner 1978). Settlers entered these ecosystems, removing the natural vegetation to make room for food crops, harvesting timber for fuel and shelter, and replacing wild herbivores with often too many domestic animals (Box 1978, Heady 1975, Rowley 1986). During 1880-1900, ecosystems in California were subjected to a combination of management stresses: severe overgrazing from high livestock numbers, the largest acreages plowed, the least informed forest practices, and the most extensive burning in the history of California (Heady 1975).

An overestimation of the productive capacity of semiarid and arid lands resulted in many failed attempts to homestead on 160 acres in the Great Plains during the late 1800s. Abandoned farm fields in western areas can take nearly 50 years to develop natural vegetation similar to the surrounding rangelands (McGinnies 1983). The more recent conversion of rangeland into cropland has been facilitated by technological developments, such as four-wheel drive tractors, electronically controlled harvesters, pesticides, fertilizers, and hybrid plant species. As a result of this new technology, the yield of wheat per inch of precipitation in the Great Plains has nearly tripled since 1930 (Lacey 1983 citing Sampson 1981). New arid land cropping technologies were given as a reason for the plowing of rangelands in the 1970s (Hendricks 1983).

Changes in riparian zones can be attributed to several factors including the number and distribution of natural and introduced large grazing animals, the alteration of flow caused by diversion of water for irrigation and reservoir storage, the multiple use of watersheds, and the present exploration for oil and gas (Skinner 1986). Erosion has been a part of the historical landscape, as large wildlife (bison) herds sought the use of water in these riparian zones (Skinner 1986). Past management activities such as channelization, water storage facilities, and vegetation clearing, in combination with livestock grazing, have resulted in a loss of 70% of the original area of riparian vegetation in the United States (Swift 1984). However, some land management activities created riparian zones where none previously existed (Skinner 1986). Cottonwood bottomlands in the northeastern Colorado were rare along the South Platte River, until large ranching operations began irrigation. The cottonwood population peaked during the 1950s but has declined since then primarily because of water management which has restricted overbank flooding (Crouch 1979).

Concern about the impacts associated with the severe overgrazing during the early 1900's (U.S. Senate 1936)—degraded rangeland, gully erosion, and loss of riparian habitat—led to management that has generally improved range condition since 1935 (Busby 1979). Recommended stocking rates and grazing systems were developed and implemented to efficiently utilize upland vegetation. These grazing systems often overutilized riparian vegetation, while maintaining the condition of rangeland as a whole (Platts 1986). Many Great Plains woody stands no longer exist in riparian areas and have been replaced by grasses and forbs. The deterioration and lack of reproduction within the remaining woody stands is attributed mostly to past heavy cattle use (Boldt et al. 1979). Along the lower Colorado River, Ohmart et al. (1977) estimated that the cottonwood community had declined from 5,000 acres in historical times to scattered groves containing a few mature individual trees. Livestock have impacted the riparian zones by trampling of the streambanks, causing loss of vegetation cover, lowering the water table, and making stream channels wider and shallower (Busby 1979, Kauffman and Krueger 1984, Platts 1979).

The introduction of exotic plant species either purposefully or accidentally has had and continues to have significant impact on the Nation's landscape. As invaders, exotic plant species can diminish forage production, but some planted exotics can enhance forage production as valuable forage, such as crested wheatgrass. In

Illinois, 811 species or 29% of the state's flora are naturalized from foreign countries (Harty 1986). Lehmans lovegrass in Arizona and buffel grass in Texas, introduced as new forage species, have invaded native stands and now dominate certain areas. The accidental introduction of leafy spurge, about 100 years ago, now means an annual loss of $20 to $30 million in forage and beef production for western farmers and ranchers, including the costs of chemical control (Wood 1987). The plant species saltcedar, introduced as an ornamental, has successfully invaded riparian areas in western United States (Horton 1977). In this situation, two management activities facilitated the change in the landscape: the introduction of an exotic plant species, and the manipulation of the flooding regime in the riparian zone. At a larger scale, government crop reduction programs have facilitated the planting of valuable, but introduced, pasture species.

The accidental or purposeful introduction of animal species includes carp, nutria, house mouse, Norway rat, European wild boar, European starling, rock dove, balsam wooly aphid, and gypsy moth (Harty 1986). Large grazing animals from other parts of the world, such as kudu and impala, are now part of many game ranches in western United States (U.S. Congress, Office of Technology Assessment 1986a). These animals provide income to ranchers, genetic reserves for threatened and endangered species, and recreational opportunities.

Brush invasion is the encroachment of undesirable perennial woody plants in ecosystems in which these shrubs are not part of the climax plant community, or the increase in shrub density where the natural density is low (USDA Soil Conservation Service 1987c). Shrubs species most common in this category include mesquite, juniper, sagebrush, several species of oak, saw-palmetto, creosote bush, and chaparral shrubs. Under dense shrub production, grass and forb production is lessened and soil erosion increases (USDA Soil Conservation Service 1987c). Invasion by shrub species has had negative impacts on habitat for wildlife species such as bighorn sheep, pronghorn, sage grouse, masked bobwhite quail, and northern aplomado falcon. Shrub invasion has had positive impacts on habitat for some wildlife species, such as mule deer (Flather and Hoekstra in press). Brush management could enhance forage production on almost 81 million acres of nonfederal rangeland. On over 17 million acres of nonfederal rangeland, brush control and the reestablishment of desirable forage plants by seeding is considered necessary to reestablish a productive rangeland ecosystem (USDA Soil Conservation Service 1987c).

VEGETATION MANAGEMENT

Existing Technologies

Resource managers manipulate the processes of energy flow and nutrient cycling in order to obtain the production of forage for livestock and wildlife and sufficient plant cover to protect the soil from wind and water erosion (figs. 17 and 22). Management decisions involve determining the suitability of the vegetation for different uses, designing and implementing range improvement practices, and manipulating the distribution, intensity, and seasonality of grazing by wild and domestic herbivores. Range improvements include special treatments, developments, and structures that can improve range forage quality or quantity or facilitate the efficient use of forage by grazing animals (Vallentine 1980).

The analysis of forage production to produce a specific output such as livestock or wildlife on an individual enterprise requires an analysis of the production system within which forage is an input (Workman 1986). The analysis of forage production requires a recognition of interrelations among the forage itself, the animal that grazes or consumes it, the soil/land resource, and the enterprise that must plan for economic survival (Tyner and Purcell 1985). This analysis reflects site-specific concerns such as the tradeoff between range improvement practices and the expected return in domestic or wildlife production. The successful implementation of these improvement practices must sufficiently increase the final output that is marketed from the enterprise before the practice is cost effective.

Practices that have been used to improve the management of rangelands may be broadly grouped: promoting desired plant species; controlling undesirable plant species, manipulating the distribution, intensity, and seasonality of grazing by wild and domestic herbivores; and controlling undesirable animal species (Vallentine 1980; U. S. Congress, Office of Technology Assessment 1981). Technology to enhance the production of herbivores is discussed in Chapter 3. Technology to enhance vegetation production includes capital intensive techniques for shrub removal or less intensive practices such as fire (table 11). Reseeding and interseeding practices have been used to replace or enhance the composition of desirable forage species when the native vegetation is of poor quality or lacking in quantity. For example, winter ranges of mule deer and domestic sheep can be enhanced by plantings or seedings of the recently released 'Hobble Creek' low-elevation mountain big sagebrush (Welch et al. 1986).

Lands that have undesirable species can be controlled by a number of mechanical, chemical, and biological methods, but success rates vary with environmental conditions and application. Mechanical plant control has included crushing, uplifting or knocking down plants, and plowing the root zone of undesired vegetation (table 11) (Vallentine 1980). The use of fire in controlling undesirable plant species has the advantages of being inexpensive and effective against non-sprouting species. Until the late 1940s and early 1950s, chemical control was limited to individual-plant treatments because most herbicides were not highly selective (Scifres 1977). Since then, the number of chemicals and control methods has increased (table 11). Aerial spraying of chemicals is particularly advantageous for rangelands with difficult terrain. The future development of chemicals that are highly specific in their effect is important to selectively manage for desired species. Biological control which is

Table 11.—Status of development and application of facilities and equipment used to manipulate vegetation for managing and improving range ecosystems of the Great Plains.

Facility or equipment item[1]	Status of development[2]	Extent of application[3]
A. Mechanical plant control		
1. Plant root extraction by plows or grubbers	3	2
2. Brush clearing by rakes, chains or rails	3	2
3. Choppers and shredders	3	2
4. Mowers	3	3
5. Handtools	3	3
B. Herbicide application		
1. Fixed-wing or helicopter sprayers	3	2
2. Vehicle mounted boom sprayers	3	2
3. Other vehicle mounted applicators	2,3	2
4. Mist sprayers	3	2
5. Subsoil injectors	3	1
6. Tree injectors	3	2
C. Seeding		
1. Broadcast seeders		
a. Fixed wing or helicopter spreaders	3	2
b. Seed dribblers	3	3
c. Blower or rotary spreaders	3	3
d. Steep slope scarifier seeder	3	1
e. Hydraulic seeder-mulchers	3	2
f. Grass seeder (spreader with cultipacker)	3	2
2. Drills		
a. Grain drills	3	3
b. Heavy-duty grain drills (pasture drills)	3	2
c. Rangeland drills	3	2
d. Presswheel drills	3	2
e. Seeder for brush littered range	2	1
3. Interseeders		
a. Range interseeders	3	2
b. Tiller seeders	3	1
c. Interseeder for rocky and brushy areas	3	2
4. Others		
a. Sodders or spriggers	2	1
b. Tree and shrub planters	3	1
D. Fire management		
1. Ignition devices	3	2
2. Fireline plows	3	2

[1]*Equipment and facilities are grouped according to their principal use. Many have a variety of applications.*

[2]*Status of development:*
1 = Undeveloped.
2 = Various stages of development, not available for general use.
3 = Fully developed and available for use; refinements may be made in existing equipment.

[3]*Extent of optimum application:*
1 = None or very limited
2 = Significant, but incomplete
3 = Complete or near complete

Source: After Lewis and Engle (1982).

the study, importation, augmentation, and conservation of natural enemies (Dahlsten 1986), can be very successful against exotic plant species. One of the earliest successes occurred in the mid-1940s when *Chrysolina* beetles were introduced into northern California to control St. Johnswort. By 1958, St. Johnswort had been reduced to less than 1% of its former abundance (Vallentine 1980). The use of grazing animals such as livestock to control weedy species is a promising area of research.

Integrated pest management (IPM) is the selection of two or more compatible pest suppression tactics for control of a single pest organism: animal, plant, insect, or

pathogen pest (Johnson 1987). Although IPM offers potential treatments for rangeland pests, managers are confronted with problems concerning the various costs and benefits of individual pest management options for rangelands. Data on the economic thresholds for selecting control methods for nearly all pests are absent (Capinera 1987). When control methods are examined for animals such as prairie dogs which have long been considered pests, research suggests that the animals may not be economical to control and are important in the enhancement of wildlife diversity and for sport hunting (Uresk 1987).

Although many technologies currently are fully developed and available for use, the extent of their implementation is often lacking (Lewis and Engle 1982). Within the Great Plains, the only mechanical plant control methods considered to be nearly complete in optimum application are mowers and handtools (table 11). Heavy equipment has been applied but not as extensively. Seeding equipment developed for steep slopes or brush-littered rangelands is less likely to be implemented than other seeding technologies for more accessible rangeland. The extent of technological application appears poor for capital-expensive treatments (heavy equipment) and for technologies for areas of likely low return (steep slopes or woody rangelands). An evaluation of improvement practices within the depressed livestock market of the last few years has not suggested the profitable implementation of many range improvement practices (Pope and Wagstaff 1987b).

Future Technologies

The future productivity of agriculture and livestock could potentially be increased by the development and implementation of 150 existing and potential technologies (U.S. Congress, Office of Technology Assessment 1986b). These technologies span improvements in plants such as genetic engineering, plant physiology, improvements in disease and pest management, and monitoring of the environment and labor-saving technologies (table 12). The future availability of such technology was based on a real rate of growth in research and extension expenditures of 2% per year, and the continuation of all other forces that have shaped past development and adoption of technology (U.S. Congress, Office of Technology Assessment 1986b). Decreases or increases in research and extension expenditures shift the future availability of these technologies (table 12). Technologies developed for croplands that can easily be implemented on rangelands and technologies developed for grain crops will impact forage production earliest. Environmental monitoring devices, communications and information management, and telecommunication devices are available today. Computer software and database systems can handle large amounts of data and aid in farm/ranch management decision analyses. Developments in this information management technology will enhance research and development in forest and rangeland management (Wisiol and Hesketh 1987).

Technologies to improve disease resistance, weed control, and the management of insects and mites were also forecast to be available before 2000 (table 12). The enhancement of photosynthetic efficiency and plant growth regulators were also available by 2000. Understanding drought resistance and tolerance, and improving water use efficiency through recombinant DNA were not forecast as being available until 2000. Plant technologies were seen as lagging behind animal technologies, and significant improvement in primary production would not occur until the year 2000 (U.S. Congress, Office of Technology and Assessment 1986b). Animal technologies will affect the production of livestock and the consequent demand for forage (Chapter 3).

The potential impact of these technologies on range plant production involves economic and social factors. The Soil Conservation Service (SCS) reported that an economic analysis of the range livestock industry showed that rangeland is more responsive to intensive management practices than to capital-intensive practices (USDA Soil Conservation Service 1987c). Much of the technology identified in table 12 is capital-intensive; however, few range improvement practices have proved profitable in the recent livestock market.

The extent that technology could improve forage production is viewed as highly significant in many parts of the United States. The application of existing technology could potentially increase forage production 100% to 200% in Southwestern ecosystems (Dwyer 1982). Similar estimates of potential improvement in range forage production were made for the Pacific Northwest grazinglands by Box (1982). In contrast, significant improvements in forage production in the Northern (NO) region will depend on the development of technologies to produce multiple resources from forested lands (Byington 1982).

AVAILABILITY OF GRAZINGLAND

Past Legislation and Land Use

Legislation has affected the management of lands in private and public ownership (table 13) and thus, indirectly, the supply of forage nationally. The early homestead acts (1862, 1873, 1877) transferred public domain land to private individuals under certain management conditions (Smith 1979). Government crop-acreage control programs can influence the acreage of land available for forage production. This influence was evident in the Soil Bank (1956) that allowed grazing and the Conservation Reserve Program (CRP) (1985) that did not allow grazing.

Grazing on public lands was important in the start of the livestock industry in western United States (Blaisdell and Sharp 1974, Rowley 1986). The use of federal lands for grazing was first regulated on forest preserves in 1897, and on public domain lands in 1934 (table 13). The poor condition of the federal lands before this time has been discussed by a number of authors (Blaisdell and Sharp 1974, Box 1978, Rowley 1986, Stoddart et al. 1975). This regulation of grazing on federal lands helped to control excessive grazing (Rowley 1986). Legislation

Table 12.—Emerging technologies for plant production and likely year of introduction under three future environments for technological development.

Technology	Technology environments: More new technology[1]	Most likely[2]	Less new technology[3]
Genetic engineering:			
Microbial inoculums	1990	1990	Never
Plant propagation	1983–90	1983–90	>1990
Genetically engineered cereals	1995	2000	2010
Enhancement of photosynthetic efficiency:			
Basic process of photosynthesis	1983	1983	1983
Photosynthetic control	1983–90	1983–90	1983–2000
Photosynthetic molecular biology and genetics	1990–2000	1990–2000	1990–2000
Mechanisms of response and adaptation to stress	1990	1983–95	2000
Plant growth regulators:			
Controlling growth/development	1984	1984	1985
Disease and insect resistance	1986	1988	1990
Overcoming environmental stresses	1986	1988	1990
Plant disease and nematode control:			
Breed cultivators	1984	1984	1984
Genetic engineering	2000	2000	2025
Bacteriocides, fungicides, and nematicides	1988	1990	2000
Biocontrol agents	1985	1990	2010
Management of insects and mites:			
Chemical controls	>1995	2000	>2000
Genetic engineering			
Pathogenic chemicals	1995	2000	2005
Plants	2000	2005	2010
Information processing	1984	1984	1984
Weed control:			
Bioregulation through chemical and biological technology	1984-2000	1984-2000	1984-2000
Allelopathic chemicals	1990	1995	2000
Crop tolerance and susceptibility to control agents	1992	1998	>2000
Biological nitrogen fixation:			
Improved strains of rhizobia	1984	1984	1984
Stress-tolerant rhizobia	1987	1990-95	1995-2000
Legumes more active in nitrogen fixation (plant breeding)	1990-95	1990-95	1990-95
Nitrogen-fixing cereals	>2000	>2000	>2000
Chemical fertilizers:			
Increasing efficiency of nitrogen use	1990	1995	2000
Decreasing energy required	1980	1980	1980
Processing of lower quality phosphate rock into fertilizers	1990	1990	1990
Ammonia from coal	1995	2000	2000
Communications and information management:			
Communication networks, data terminals, software	1985	1985	1985
Manufacturing management systems	1987	1990	2000
Expert systems	1990	1992	1997
Monitoring and control:			
Sensors, controllers, displayers	1984	1984	1984
Water and soil-water-plant relations:			
Understanding drought resistance/tolerance	2000	2020	2050
Plant breeding	1984	1984	1984
Biotechnology:			
Water use efficiency	2010	2030	2050
Water management	1984	1984	1984
Photovoltaic systems	1995	1995	2010

Table 12.—Continued

Technology	Technology environments: More new technology[1]	Most likely[2]	Less new technology[3]
Soil erosion, productivity, and tillage:			
Conservation farming systems	1995	1995	1995
Assessing erosion and its impact	1995	1995	2000
Reclaiming lands	1995	1995	>2000
Organic farming:			
Biocides	1984	1984	1984
Reduced soil erosion	1984	1984	1984
Self-sufficiency for nutrients	1984	1984	1984
Minimum tillage with minimal biocide use	1990	1990-95	2000
Rotations			
Use	1984	1984	1984
Knowledge	1990	1990-95	2000
Labor-saving technologies:			
Robotic farming of grains	1995	2000	2010
Crop separation, cleaning, and processing:			
New methods for separating and cleaning grain	1995	1995	1995
Infield or onfarm processing:			
Forage	1990	1990	2000
Oilseed	1984	1984	1984
Engine and fuels:			
Adiabatic compression ignition engines with turbocompounding	1990	1990	1990
Electronic engine controls	1985-86	1986	1986
Alternative fuels			
Grains	1984	1984	1984
Cellulose	1995	2000	2010
Land management:			
Conservation tillage	1984	1984	1984
Controlled traffic farming	1987	1990	1995
Customed-prescribed tillage	2000	2005	2020
Multicropping	1984	1984	1984
Telecommunications:			
Digital communication	1995	2000	2010
Fiber optics	1990	2000	2010
Personal computers	1985	1985	1985
Videotex and teletext	1985	1985	1985
Value-added networks	1985	1985	1985
Integrated services digital network	1990	1990	>2000
Remote sensing	1985	1985	1985

[1]*Assumes to year 2000: (1) a real growth rate in research and extension expenditures of 4%, and (2) all other factors more favorable than those of the most likely environment.*

[2]*Assumes to year 2000: (1) a real rate of growth in research and extension expenditures of 2%, and (2) the continuation of all other forces that have shaped past development and adoption of technology.*

[3]*Assumes to year 2000: (1) no real rate of growth in research and extension expenditures, and (2) all other factors less favorable than those of the most likely environment.*

Source: After U.S. Congress, Office of Technology Assessment (1986b).

has continued to affect the management of federal lands (table 13). Recent legislation has emphasized the multiple use of federal lands (1960), the need to examine potential impacts of management (1969), the management of wild horses and burros as part of Forest Service (FS) and Bureau of Land Management (BLM) grazing management (1971), the decadal assessment of current and future production of natural resources on all forest and rangelands with the development of a national program for FS (1974), and the need for a planning process on all National Forest System (NFS) lands and all BLM-administered lands (1976). These factors affect the supply of forage as it is allocated to each of these uses on federal lands.

Table 13.—Legislation affecting the management of forest and rangelands in the United States.

Year	Law	Consequences
1862	Homestead Act	Encouraged settlement of West.
1873	Timber Culture Act	Settlement of 160 acre if trees planted.
1877	Desert Land Act	Land sold for 25 cents per acre if irrigated and cultivated for 3 years.
1897	Organic Administration Act	Regulated use of Forest Preserves (est. 1891)
1905	Transfer Act	Forest reserves transferred from USDI to USDA; created the Forest Service.
1906	Meat Inspection Act	Governed the slaughtering, packaging, and handling of meat shipped intrastate.
1916	Federal Farm Loan Act	Farmland banks created.
1920	Mineral Leasing Act	Allowed the Government to lease national forest lands for mining.
1924		Gila Wilderness, NM, became first official wilderness in NFS.
1928	Wool Standards Act	Appropriated funds for wool standards.
1928	McSweeney-McNary Act	Established a program of forest research.
1934	Taylor Grazing Act	Designated grazing on public domain lands to be regulated by the BLM.
1950	Cooperative Forest Management Act	Federal cooperation with states to provide technical services to private forest landowners.
1952	Independent Agencies Appropriation ACT	User fees must be self-sustaining, uniform, fair and equitable to public and user.
1954		National Grasslands added to Forest Service
1956	Agricultural Act	Financial assistance to farmers converting cropland to conservation uses (Soil Bank).
1960	Multiple-Use and Sustained Yield Act	National forest management to recognize multiple resources and uses.
1964	Wilderness Act	Creates National Wilderness Preservation System.
1964	Trade Agreement	US-Australia agreement limits Australian export of beef, veal, and mutton.
1964	Tariff Act of 1930 Amendment	Allowed the free importation of certain wild animals and imposed quotas on certain meat and meat products.
1969	National Environmental Policy Act	Analyses required for all management potentially affecting the environment.
1971	Wild Free-Roaming Horse and Burro Act	Management of wild horses and burros on FS and BLM lands now the responsibility of FS and BLM.
1973	Endangered Species Act	Federal management must not jeopardize the existence of endangered plant or animal species.
1974	Forest and Rangeland Renewable Resource Planning Act	Assessment of current and future production of natural resources on all forest and rangelands and development of a national program.
1974	Federal Noxious Weed Act	Provide for control of noxious weeds.
1976	Federal Land Policy and Management Act	Requires planning on BLM lands.
1976	National Forest Management Act	Requires planning process on all NFS lands.
1976	Beef Research and Information Act	Establish a program of research, information, and promotion for beef cattle and beef products.
1978	Public Rangelands Improvement Act	Grazing fee formula for FS and BLM, and requires analysis of fee in 7 years.
1978	Forest and Rangeland Renewable Resources Research Act	Authorized USDA research to be conducted on renewable resources.
1985	Food Security Act	CRP, sodbuster, swampbuster, conservation compliance.

Source: Smith (1979); USDA Forest Service (1983b); USDA Forest Service, and USDI Bureau of Land Management (1986).

Land Use at the National Level

Land Use Inventories

A series of land use inventories based on available statistics has been summarized by the Economic Research Service and its predecessor agencies (Frey 1973, 1979, 1982; Frey and Hexem 1985; Frey et al. 1968; Wooten and Anderson 1957; Wooten et al. 1962). Categories and area coverage have been generally comparable since 1945. This compilation of land use data from public agencies such as FS, Bureau of Census, BLM, and SCS provides a useful framework within which changes in the supply and demand for land can be analyzed (Frey and Hexem 1985).

Major land uses include forest land, cropland, and pasture and rangeland. The interpretation of these land-use trends is based on land use, not land cover. In this historical data, land with tree cover that is designated as wilderness is removed from the forest land category. Thus, data for the major land use categories of forest land, and pasture and rangeland do not include military lands, national parks, or wilderness area. These land-use inventories do not separate pasture from rangeland, thus long-term trends are available only for this combination. Historical records are also kept on special-use areas, such as roads, railroad rights-of-way, airports, federal and state parks, wilderness areas, wildlife refuges, defense, and industrial areas.

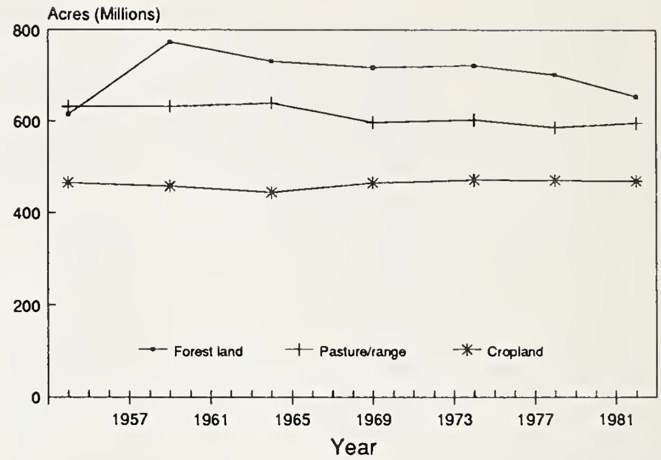
Major Land Use Trends

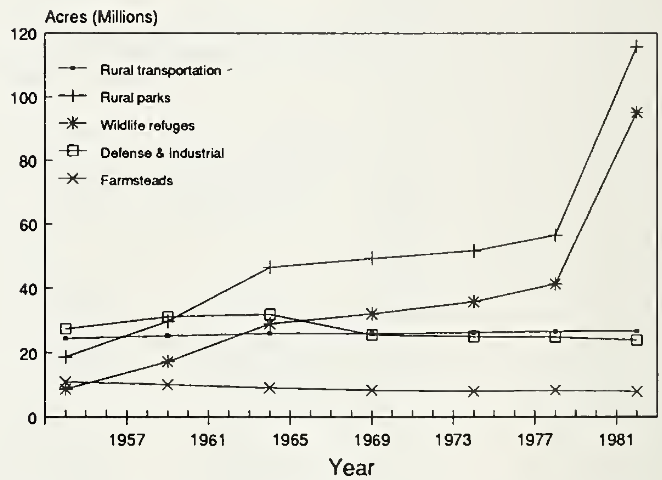
Since 1954, shifts in major land uses have been minor at the national level (fig. 23). The increase in forest land between 1954 and 1958 is the result of the inclusion of Alaska's lands with the U.S. land base. Since 1958, forest land conversions to land uses such as crop, pasture, and urban has resulted in a decrease in forest area. The legislated conversion of forest land into wilderness contributes to the decline in forest area and the increase in rural parks and wildlife refuges (fig. 23). Total cropland has remained fairly constant at around 450 million acres. Pasture and rangeland together form the second largest use of land in the United States. Acres in this land use category show a decline of 4% over this period, because this land has been converted to other uses such as agriculture or urban.

The most rapid land use change has been in the rural parks and wildlife refuges (fig. 23). This increase is associated with the Wilderness Act of 1964 (table 13) and greater interest in recreation and wildlife (Cordell in press, Flather and Hoekstra in press). In 1982, national and state parks and related areas totaled 116 million acres, and federal and state wildlife agencies administered an additional 95 million acres.

Trends in the Availability of Grazingland

The Nation's grazingland base includes forest land, rangeland, pasture, and cropland used for pasture.





NOTE.--Data from periodic inventories. Most recent inventory: 1982.

Source: Frey (1973, 1979, 1982), Frey and Hexem (1985), Frey et al. (1968), Wooten and Anderson (1957), Wooten et al. (1962)

Figure 23.—Major uses of land in the United States, 1954-1982.

Changes in this base[4] have been estimated over time (Frey and Hexem 1985). Grazing available on forest land is estimated from the area in open forests, arid woodlands, and lands reverting to forest which have forage. Changes in nonforested pasture and rangeland include cropland pasture. Frey and Hexem (1985) reported that between 1969 and 1982, grazingland had declined 8%. Declines were steady in both forest grazing and nonforested pasture and rangeland.[5]

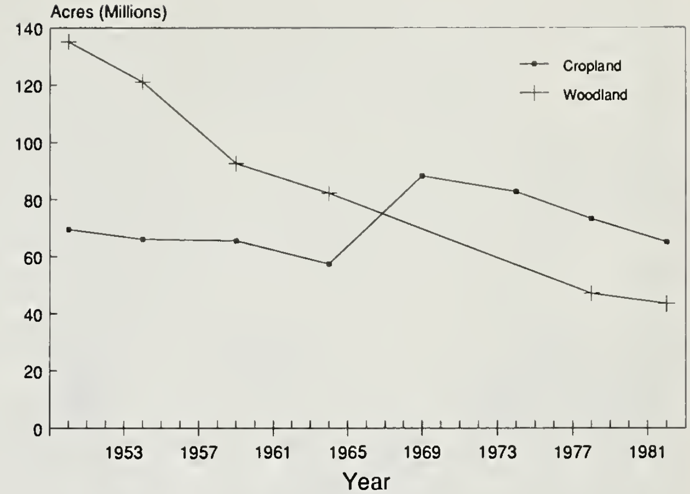
[4]*These estimates exclude land on which grazing occurred before or after crops were harvested, and areas totaling about 60 million acres in federal grazing districts and range allotments that have little value for grazing but which are intermingled and managed with productive federal range. In addition, these estimates do not include special land uses such as wilderness or wildlife refuges.*

[5]*Nonforested pasture and rangeland in this historical time series include cropland used for pasture as well as pasture and rangeland.*

Several forces combine to cause the long-term decline in pasture and rangeland: (1) fluctuating demands for crop products shift acres between cropland and other uses such as pasture and rangeland, particularly in the South; (2) withdrawal of land for recreational, wildlife, and environmental purposes, particularly in the western United States; and (3) withdrawal of land for urban areas across the Nation (Frey and Hexem 1985). Since 1949, 41 million acres of pasture and rangeland have been converted to other uses. Since 1969, this decline appears steeper because 30 million acres have been converted to other uses in only 13 years. Although these estimates reflect some inconsistencies in classification and measurement, Frey and Hexem (1985) maintained that a long-term decline has occurred in pasture and rangeland, and that the 30 million acres converted to other uses since 1969 was more representative of the long-term rate of decline. This decline represents an annual loss of 0.33% in total nonforested pasture and rangeland.[6]

Cropland used for pasture, one component of pasture and rangeland area, fluctuated from a record low of 57 million acres in 1964 to a record high of 88 million acres in 1969 (fig. 24). These fluctuations correspond with government set-aside programs for crop surpluses. Cropland used for pasture represents a small total acreage when compared with the pasture and rangeland total, 65 million compared with the 598 million acres reported by Frey and Hexem (1985) for 1982. This cropland, however, is a highly productive component and represents the only available grazingland in some areas in certain seasons. The sensitivity of this grazing resource to conversion to crop production varies with the region. Cropland pasture makes up a proportionally larger amount of land in fertile agricultural areas such as the Corn Belt (Iowa, Illinois, Indiana, Ohio, and Missouri). In other areas such as the Appalachian region, cropland pasture is associated with small, irregularly shaped, and scattered fields not as likely to be converted to crop production (Frey and Hexem 1985).

Forest grazing by livestock has declined 50% since 1949. Although these estimates do not include special land uses such as wilderness or wildlife refuges, this decline in forest grazing does include changes in forest species such as improved commercial timber stock, increases in stand density, and improvements in livestock feeding and forest management practices (Frey and Hexem 1985). Areas designated as wilderness on NFS lands are grazed by wildlife and, if previously permitted, livestock. Thus, the historical forest grazing acreages probably underestimate forest land available for grazing. The total amount of woodland pasture on farms has declined from nearly 140 million acres in 1950 to less than 50 million in 1982 (fig. 24), based on the Census of Agriculture statistics (USDC Bureau of Census 1984). Thus, the woodland available for grazing on farms has dramatically declined since 1950. As a percent of total woodland, the amount grazed has remained around 50% (USDC Bureau of Census 1984).



NOTE.--Data based on periodic inventories. Most recent inventory: 1982.

Source: USDC, Census of Agriculture (1984)

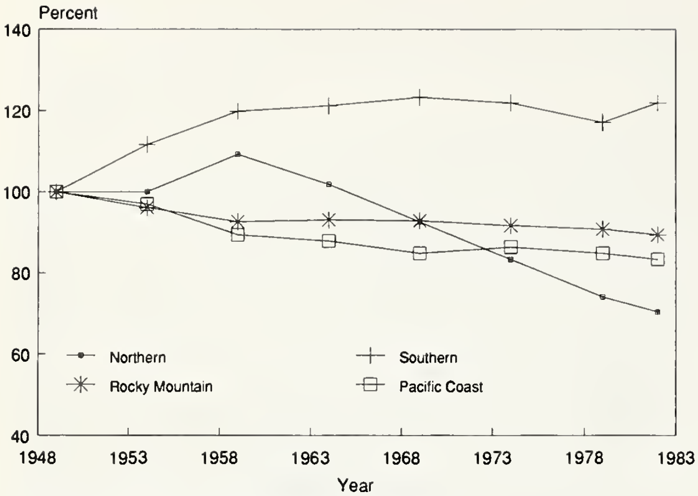
Figure 24.—Area of woodland pasture and cropland used only for pasture or grazing in the United States, 1950-1982.

Regional Trends in Pasture and Rangeland Use

Conversions of pasture and rangeland varied regionally across the United States in 1949-82 (fig. 25). Conversions of pasture and rangeland to other land uses were greatest in the NO and PC regions with a 30% and 17% decline respectively, relative to 1949 acreage. These regions had the fewest acres of pasture and rangeland. The increase of pasture and rangeland in the SO region reflected a substantial reclassification of noncommercial forest to open rangeland in Oklahoma and Texas, a decline in cropland used for crops with the associated increase in cropland used for pasture, and the clearing of commercial forest land, particularly in South Carolina, Georgia, Florida, Alabama, Oklahoma, and Texas. This increase in the South was not large enough to compensate at the national level for decreases in other regions, notably in the Rocky Mountain region where areas were withdrawn for parks, wilderness, or reclassified as unsuitable for grazing (Frey and Hexem 1985).

Increased conversions of rangeland during the late 1970s were related to a variety of factors: (1) a depressed cattle industry contrasted with a profitable wheat sector encouraged the diversification of ranching operations to include wheat production (Wight et al. 1983, Young

[6]Frey and Hexem (1985) reported 890 million acres in 1969 and 820 million acres in 1982 of grazingland—forest, pasture, and range. This 70 million acres loss represents an annual loss of 0.6% per year, or 5.3 million acres per year from the grazingland base. When only pasture and rangeland acres are examined, 692 million acres in 1969 and 662 million in 1982, the annual loss is 0.33% or 2.3 million acres per year. When the declines in forest grazing are included with pasture and rangeland, the annual decline in grazingland area would represent a total decline of 53 million acres in the grazingland base over 10 years. Forest grazing, however, has declined for a number of reasons, including changing management practices which exclude livestock grazing. Thus, while the CRP land will return acres to forest land, changes in management on forest land could impact forest grazing much more significantly.



NOTE.--Data based on periodic inventories. Most recent inventory: 1982.

Source: Frey and Hexem (1985)

Figure 25.—Trends in pasture and rangeland area, relative to 1949, by assessment regions in the United States.

1984); (2) cash-flow problems encouraged ranchers to sell all or part of their land (Huszar and Young 1984); (3) increased credit availability on cropland as opposed to rangeland, and pressures from lending institutions to convert rangeland to cropland (Huszar and Young 1984, Young 1984); (4) price differentials in the market price of rangeland and cropland (Roath 1983, Watts et al. 1983); (5) incentives from government farm programs and income tax provisions that enhance the profitability of conversions (Heimlich 1985, Watts et al. 1983); (6) new technological improvements suggesting that semi-arid lands could be profitably cropped (Hendricks 1983); and (7) imperfect knowledge about climatic conditions in the arid regions suggesting to prospective buyers a possibility for farming (Laycock 1983).

Based on Frey and Hexem (1985), annual conversions of pasture and rangeland to other uses for 1969-82 period were:

Region	**Annual Conversion** million acres/year
Pacific Coast	0.08
Southern	0.15
Northern	0.92
Rocky Mountain	1.20

These annual rates can vary considerably with fluctuations in the demand for land for crop production. Schenarts (1981) reported that 31.9 million acres of pasture and rangeland alone were converted to cropland during 1967-75. Conversions of cropland to other uses, such as urban, exceeded the conversions into cropland over this period and the Nation's total cropland acreage decreased. The annual conversion of pasture and rangeland to cropland during 1967-75 was 0.2 million acres for the Pacific Coast region (2.5 times the 1969-82 rate), 1.2 million acres for the Southern region (8 times the 1969-82 rate), 1.1 million acres for the Northern region (1.2 times the 1969-82 rate), and 1.4 million acres for the Rocky Mountain region (1.2 times the 1969-82 period).[7] The conversion of pasture and rangeland to urban land use and the return of cropland to pasture and rangeland are not included in these conversion rates. These higher conversion rates indicate a greater loss of pasture and rangeland when cropland demand is high, as it was during 1967-75.

Table 14.—Rangeland plowed in the northern and central Great Plains States.

State	Acres plowed	Time period	Source
Colorado	572,000	1978-83	SCS
Kansas	15,000	1978-83	SCS
Montana	762,000	1970-83	Montana ACD[1]
Nebraska	400,000	1978-83	SCS
North Dakota	849,000	1967-83	SCS
South Dakota	759,000	1974-82	SCS
Wyoming	33,000	1977-83	SCS (Laramie Co.)

[1]*Montana Association of Conservation Districts, available from 22 of 59 Soil Conservation Districts and do not include Phillips, Custer, and Garfield districts where plowing occurred in 1982-83.*
Source: Laycock (1983).

Concern about the recent plowing of fragile rangelands has provided several additional estimates of the historical rangeland conversion to cropland in the Great Plains. Laycock (1983) presented estimates of grassland acres plowed in the northern and central Great Plains (table 14). For the seven states represented, an estimated 0.41 million acres of rangeland were converted to cropland annually in 1967-83 (table 14). Again, this represents rangeland plowed only for conversion to cropland. Frey (1983) reported that historic levels of land cropped in the Great Plains were greater than cropland currently in production, 132.5 million acres versus the 91 million acres in 1978. Cropping was extensive in most Great Plains counties in 1919-29 and 1944-54. Frey (1983) suggested that if acreage control programs had not been in effect, more counties would have had record acres in crop production during the 1970s. Thus, the conversion of rangeland to cropland has been high during periods of high crop demand, and in some local areas, the rate of conversion is quite high (table 14). Heimlich (1985) reported that conversions of pasture and rangeland during 1975-81 accounted for between 64% and 84% of new cropland in all regions of the United States. Thus, range and pasture serve as a reservoir for new cropland in all parts of the country.

[7]*Conversion of pasture and range to cropland during 1967-75 totaled 1.7 million acres for the PC region, 10.0 million acres for the SO region, 8.6 million acres for the NO region, and 11.6 million acres for the RM region. For this 8 year period, annual conversion rates are 0.2 million acres, 1.2 million acres, 1.1 million, and 1.4 million acres, respectively.*

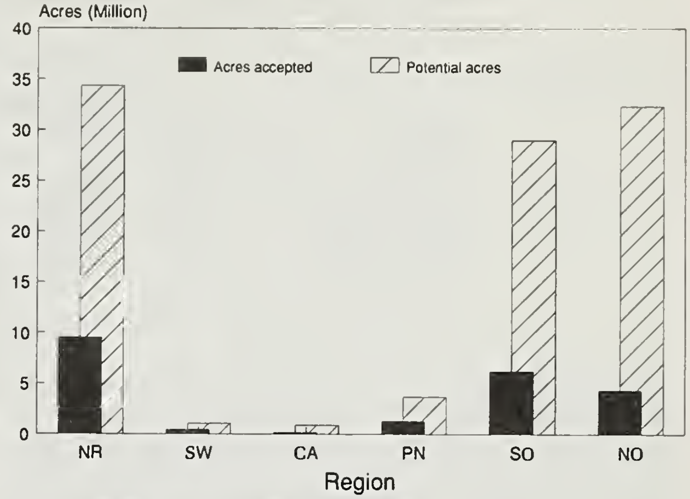
Government Agricultural Programs and Land Use Shifts

Programs designed to reduce crop surpluses have been short-term where cropland was enrolled annually and long-term where cropland could be enrolled for up to 10 years. These programs affect the demand for cropland and consequently the rate at which rangeland is converted to cropland. Thus, consideration of current and future government agricultural programs is necessary to project future rangeland acres.

Recent concerns that the Dust Bowl lessons were being relearned in the conversion of highly erodible pasture and rangeland led to legislation at county, state (Lacey 1983, Roath 1983), and national levels (Food Security Act of 1985) restricting the plowing of fragile rangelands. The Food Security Act of 1985 included several subtitles aimed at reducing crop surpluses and environmental damages associated with cropland use. The objective of the Conservation Reserve subtitle was to provide a monetary incentive to remove highly erodible cropland from production. This incentive program is referred to as the Conservation Reserve Program (CRP). The objective of the Highly Erodible Land Conservation subtitle was to remove highly erodible cropland from production as a requirement for continued eligibility for commodity program benefits. The latter subtitle contains a "sodbuster" provision wherein the plowing of highly erodible land that is not currently cropped would cause the operator to become ineligible for price-support payments, farm storage facility loans, crop insurance, and disaster payments. A similar provision called "swampbuster" restricts the plowing of wetlands. The Highly Erodible Land Conservation subtitle also contains a conservation compliance provision wherein future commodity program benefits are denied to producers who do not have specific conservation plans on highly erodible cropland now in production. These provisions were intended to take highly erodible land out of crop production, reduce erosion levels on highly erodible land, and to stem the tide of highly erodible land conversion to cropland.

The CRP is scheduled to retire at least 40 million acres of cropland by 1990. Enrollment, as of mid-1987, was 22.9 million acres. Once a farmer's bid is accepted into the program, a permanent vegetation cover must be established on the acres enrolled and the vegetation cannot be commercially harvested or grazed by livestock for the duration of the 10-year contract, except where the Secretary of Agriculture permits, as in a drought or similar emergency (Dicks et al. 1987), as occurred in the summer of 1988. The land can be used profitably for wildlife grazing through hunting or recreation. Although most acres are being planted with a permanent cover crop of either tame or native grass, over 1.2 million acres have been accepted for tree plantings, mostly in the SO region (USDA Agricultural Stabilization and Conservation Service 1987).

Enrollment in the CRP as of the fifth sign-up in mid-1987 was largest in the Northern Rocky Mountain (NR) region and least in the California (CA) region (fig. 26).



NOTE.--Hawaii included in CA Region; 29,000 acres in Alaska not shown.

Source: USDA, Agricultural Stabilazation and Conservation Service (1987)

Figure 26.—Conservation reserve program as of the fifth signup (August 1987).

Each of the states of Colorado, Kansas, Montana, North Dakota (NR region), Iowa, Minnesota, Missouri (NO region), and Texas (SO region) have over a million acres enrolled. The national average size of the contract is 110 acres, although the size varies by region (USDA Agricultural Stabilization and Conservation Service 1987). If the regional contributions remained the same as shown in figure 26, then doubling these acres gives an indication of the likely regional distribution of enrolled acres when the national cap of 45 million acres is reached.

Heimlich (1985) suggested that the conditions favorable to land conversion during 1975-81 are not likely to reoccur in the immediate future. Hexem and Krupa (1987) mentioned factors that may discourage future cropland conversions: (1) less favorable cost/price relationships since 1981, (2) the Food Security Act of 1985, (3) changes in the federal tax code eliminating investment tax credits, capital gains exclusions, and the alteration of land development cost deductions. All regions have land that could potentially be placed in crop production (table 15). The largest areas of land with high potential for conversion occur in North and South Dakota, Nebraska, Kansas, Iowa, Missouri, Indiana, Illinois, Ohio, Oklahoma, and Texas. Seventy-six percent of the national acreage with high potential for conversion to cropland is currently in pasture and rangeland (Hexem and Krupa 1987).

LAND USE CHANGES AND RESOURCE MANAGEMENT: A REGIONAL CASE STUDY

Past assessments of natural resources have relied on a limited application of analytical approaches to project

Table 15.—Regional acreage (1,000 acres) with high and medium potential for conversion to cropland, 1982.

Region	Pasture and rangeland			Forestland		
	High	Medium	Total	High	Medium	Total
Northern	7,066	13,988	21,054	2,324	11,467	13,791
Southern	11,476	34,902	46,378	4,701	20,002	24,702
Rocky Mountain	7,317	28,406	35,723	82	429	511
Pacific Coast	1,165	3,715	4,880	144	1,837	1,981

Source: Table 5 from Hexem and Krupa (1987).

resource supplies and inventories. These assessments have been criticized for not analyzing future resource production in a multiple resource context (Schweitzer et al. 1981). In response to such criticism, Joyce et al. (1986) developed a regional modeling framework that analyzed multiple resource response to land management activities. The SO region of the United States was chosen as the test area for the application of this framework. This study, the first of its kind at the regional level, represents a prototype of how future national assessments may address regional multiple resource production.

Modeling Approach

Four distinct but closely related systems of models were linked in a multiresource framework (Joyce et al. 1986). The Timber Assessment Market Model (TAMM) estimated the future demand for wood products and the roundwood harvest needed to meet this demand (Adams and Haynes 1980). The Timber Resource Inventory Model (TRIM) projected changes in timber inventory, growth, and harvest on timber stands defined by ownership, timber management type (natural pine, planted pine, oak-pine, upland hardwoods, and bottomland hardwoods), and site class (Tedder et al. 1987). Changes in major land uses (forest, pasture/rangeland, cropland, and human-related land), timber management type conversions, and ownership were simulated with the Southern Acreage Model (Alig 1985). The impact of land area and timber management changes on the southern landscape were simulated by using resource models for white-tailed deer, wild turkey, and red-cockaded woodpecker (Flather et al. 1989), trout (Flebbe et al. 1988), water quantity (Sisler 1986), and forage (Joyce in prep.). A summary of the results for all resources is presented in USDA Forest Service (1988d). The results of the forage analysis will be presented here.

Forage Production Models

The objective of the forage component of this study was to develop production estimates based on land use, timber stand descriptions, timber management activities, and environmental characteristics. The forage model projects forage production on pasture, range, and forest land by using environmental and management factors specific to each land type (Joyce 1988, in prep.). This study included all states in the SO region (fig. 1) except Kentucky and the western parts of Oklahoma and Texas. The South Central subregion consisted of Alabama, Mississippi, Louisiana, Arkansas, Tennessee, and the eastern parts of Texas and Oklahoma. The Southeast subregion included Virginia, North and South Carolina, Georgia, and Florida.

The modeling approach for pasture and rangelands is patterned after Sharp et al. (1976) where rates of production specific to each land type were used to estimate, along with acres within each land type, the forage production at the state level. Range forage production rates were taken from the Range Site Descriptions developed by SCS personnel within each state. Pasture forage production rates were estimated by using hay production within each state (U.S. Department of Agriculture 1984). On forested stands, the modeling approach follows Joyce and Baker (1987) where forest overstory characteristics such as timber type and volume, management practices such as burning history, and environmental characteristics such as precipitation, were statistically related to forage production. Timber stand characteristics significantly associated with forage production varied by timber management type and age class (Joyce 1988).

Modeling the possible impacts of changing land use and timber management on forage production requires a number of assumptions. These assumptions reflect acknowledgment of factors influencing forage production that could not be quantified in the model. Specifically, it was assumed that forage production changes on forested lands over the projection period are the result of changes in forest stand characteristics. Consequently, environmental factors that influence understory vegetation (e.g., climate change) are assumed to remain similar to past and current values. Timber management practices are assumed not to change in a way that will affect forage production responses over the projection period. For example, planting practices in pine plantations are assumed not to change tree density and spacing in such a way as to increase light reaching the forest floor. Pasture management practices, such as fertilization, are assumed not to change in a way that will affect forage production. Incorporating these factors into a quantitative analysis of forage production at the regional level will require further research.

Results

A future scenario was developed to represent the likely demand for timber products and the level of timber management required to ensure that the timber supplies would meet that demand for 1985 to 2030. A set of assumptions concerning population growth, economic growth, and timber management were used to generate the timber and land area projections (USDA Forest Service 1988d). A panel of forestry experts from the South, including forest industry, state forestry, and federal agency personnel developed the assumptions concerning likely future timber management actions.

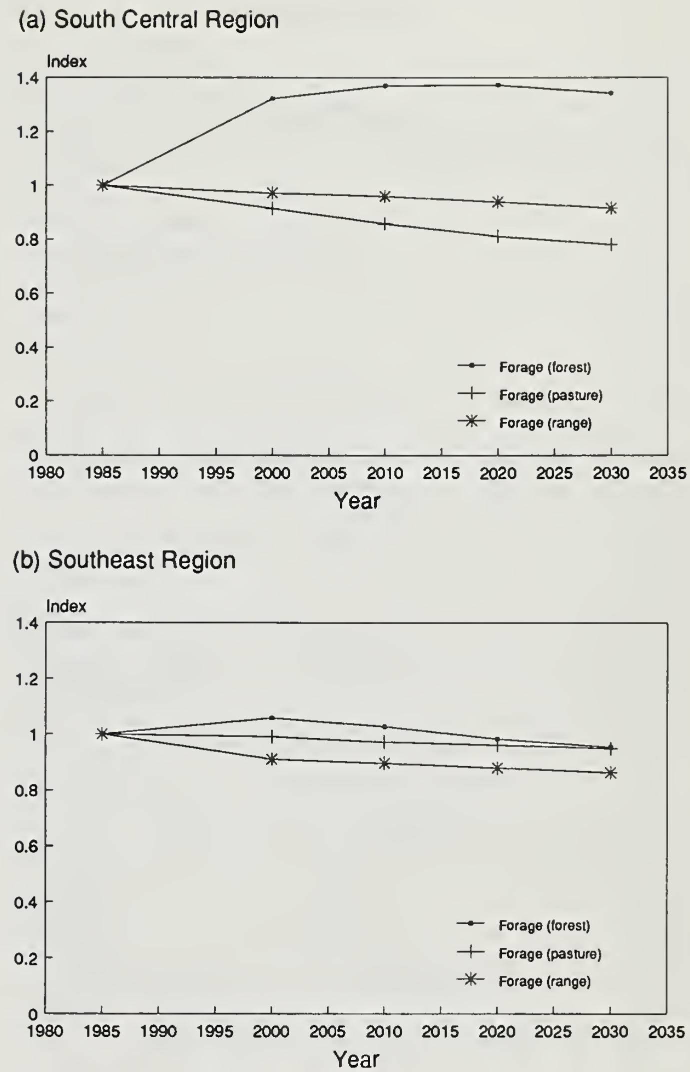
Under this future, land area shifts over the entire South were dominated by a reduction of forest land by 3% and an increase in human-related land by 50%. Pasture and rangeland acres declined 7 million acres, or 14% over the projection period for the entire South. Acres in planted pine increased substantially, from 5% of the southern landscape to nearly 15%. These acres come primarily from the conversion of natural pine, but acres of upland hardwoods and oak-pine are also converted to planted pine.

The total production of forage from all sources decreased over the projection period (fig. 27). The overall decrease reflected the southwide conversion of pasture and rangeland acres to other land uses. Forage production on forested stands increased as the older stands were harvested and regenerated, however, this increase did not compensate for the larger decreases in pasture and rangeland forage. Other factors that contributed to the increase in forest forage production included forest land conversion to planted pine types having a relatively more open canopy and management emphasis on reduction of brush.

Between 80% to 95% of the pasture in the South is currently grazed (USDA Soil Conservation Service 1987a). The results of this study suggest that if grazed roughage demands stay at their current level, forage on pasture and rangelands will be insufficient to meet the demand. Forest lands represent an extensive reservoir of grazed roughages as less than 10% are currently grazed (USDA Soil Conservation Service 1987a). The use of this forage reservoir to compensate for the decline in forages from pasture and rangelands will need to reverse an historical trend of decreased grazing on forested lands (Frey and Hexem 1985).

The extensive conversion to planted pine and the need to manage understory vegetation on these stands to reduce competition with the young seedlings suggests a future need for vegetation management (Pearson 1987). Increasing constraints on chemical control will necessitate alternative methods to manage this vegetation. The use of livestock as a biological vegetation control tool shows great potential in the South (Pearson 1987) as well as other places nationwide (Krueger 1987).

The results of this case study suggest methods to address multiresource interactions in national assessments. Resource models for timber, wildlife, forage, fish, and water were linked at the regional level for the first time. The importance of a consistently and completely



Source: Joyce (1988)

Figure 27.—Indexed response of resources—baseline scenario.

defined land base was demonstrated in the linkages across these models. This analysis is an impact analysis that is entirely driven by the land use and the timber inventory projections. Traditionally, the use of land for grazing has been considered residual use, grazed when the land can be used for nothing else. Additional research is needed to adapt this methodology to other regions and to improve the feedbacks between resources during the projection period.

SUPPLY OF PUBLIC FORAGE

The supply of forage on public lands is reflected in the number of Animal Unit Months (AUMs) permitted to graze each year. Although these numbers are influenced by factors affecting the demand of forage on public lands, use of public grazing is an indication of the supply of forage.

National Level

Numerous federal, state, and local government agencies permit grazing on public lands. The largest suppliers of permitted grazing on federal lands are the FS with 10 million AUMs and the BLM with 12.5 million AUMs in 1986 (table 9). The 7 million AUMs that other western agencies permit is probably a minimum estimate, as only 113 out of 257 sites had AUM records (Bartlett et al. 1983). The Bureau of Indian Affairs was the largest supplier of grazing in their survey. More complete records indicate the Bureau of Indian Affairs supplies over 4.9 million AUMs of grazing (Kipp pers. comm). Other federal agencies reported by Bartlett et al. 1983 included National Park Service (81,752 AUMs), Fish and Wildlife Service (264,723 AUMs), U.S. Army (57,463 AUMs), U.S. Navy and Marines (23,632 AUMs), Agricultural Research Service (19,920 AUMs), U.S. Air Force (18,265 AUMs), Bureau of Reclamation (8,011 AUMs), and the U.S. Army Corp of Engineers (3,610 AUMs).

Historical records on NFS lands indicate that grazing has remained fairly constant since 1953 (fig. 28a). The increase in 1954 is the addition of National Grasslands to the Forest Service (table 13). The slight decline, less than 1 million AUMs, is the result of a decline in the number of sheep and goats grazing NFS lands. Reductions in cattle allotments have also occurred in some regions. Livestock grazing on BLM-administered lands[8] has declined as a result of reductions in stocking rates on some allotments and a transfer of BLM-administered lands to other agencies (USDI Bureau of Land Management 1984) (fig. 28b). Although a breakdown by animal type was not available for Section 15 lands[9] from BLM, trends on the Section 3 lands[10] indicate a similar decline in sheep as was seen on NFS lands.

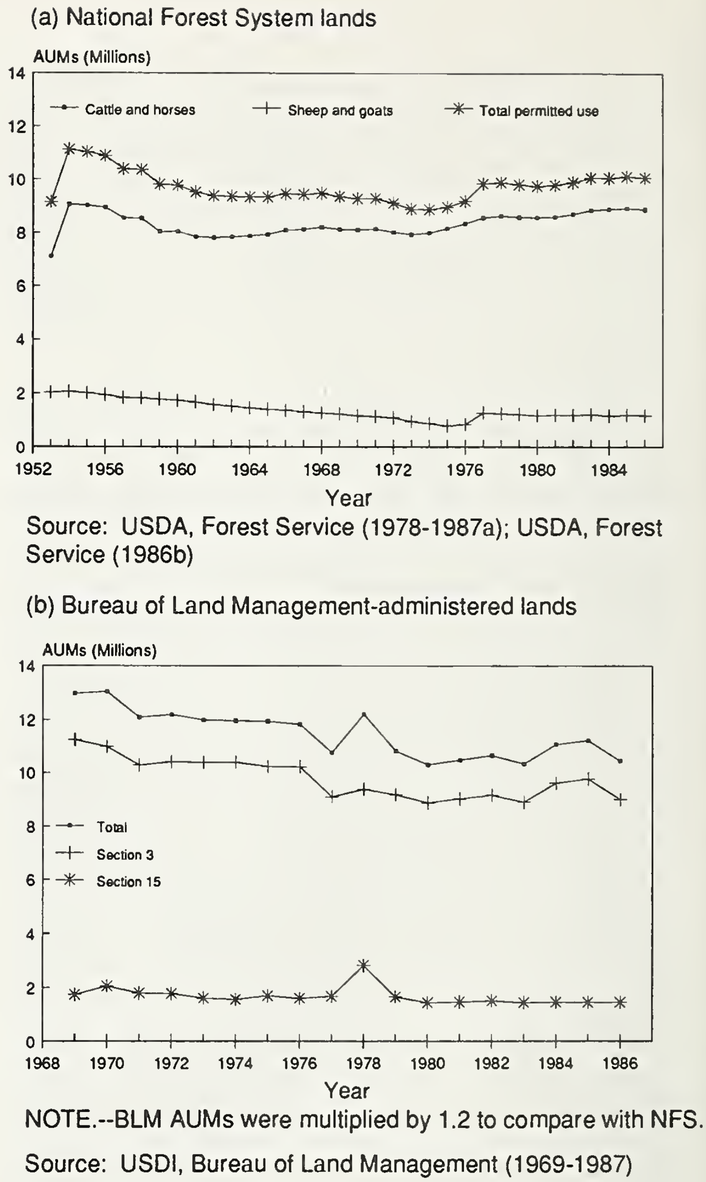


Figure 28.—National grazing use.

Regional Supplies from Forest Service and Bureau of Land Management

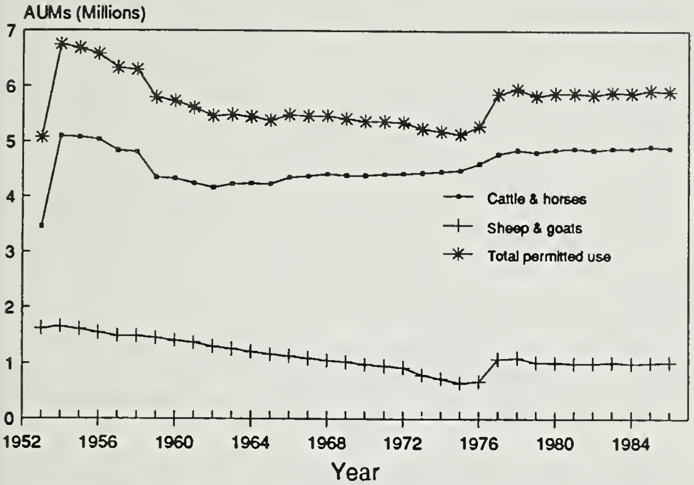
In the NR region, elevations of rangelands suitable for grazing vary from 800 feet in Kansas to over 12,000 feet on alpine ranges. Plant communities along this elevational gradient include sandhill prairies, sagebrush-grass, ponderosa pine and mountain bunch grass communities, aspen, mountain meadows, and alpine meadows (fig. 2). Although grazingland occurs on federal, state, and privately-owned land, livestock enterprises with their year-round cattle and sheep operations receive an essential component in their grazing balance from federal lands (USDA Forest Service 1981a). Paralleling the national trend, the number of AUMs permitted to graze on public lands in the NR region has declined in 1953-86 (figs. 28 and 29). The number of AUMs on NFS lands peaked at nearly 7 million in 1954 and has declined since then to about 6 million AUMs in 1985 (fig. 29a). The early rise in 1954 reflects the inclusion of National Grasslands into the NFS, increasing the AUMs available by nearly 2 million. Cattle grazing dominates NFS use in this region. Horse use in this region is mainly pack and saddle animals for camping, hunting, and fishing trips (USDA Forest Service 1981a, 1984b). Sheep AUMs in Utah and Nevada alone totaled nearly 1 million AUMs in the 1950s but have declined to near 750,000 in the 1980s.

[8]*To compare BLM AUMs with FS AUMs, multiple BLM AUMs by 1.2 (USDA Forest Service and USDI Burea of Land Management 1986).*

[9]*Section 15 lands on BLM are public lands administered by BLM outside of grazing districts in western states leased for grazing purposes under authority of Section 15 of the Taylor Grazing Act.*

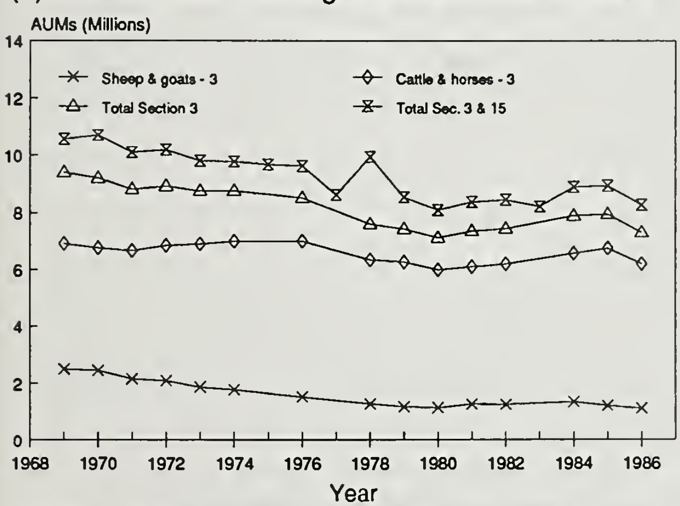
[10]*Section 3 lands are public lands within grazing districts administered by BLM in western states leased for grazing purposes under authority of Section 3 of the Taylor Grazing Act.*

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands

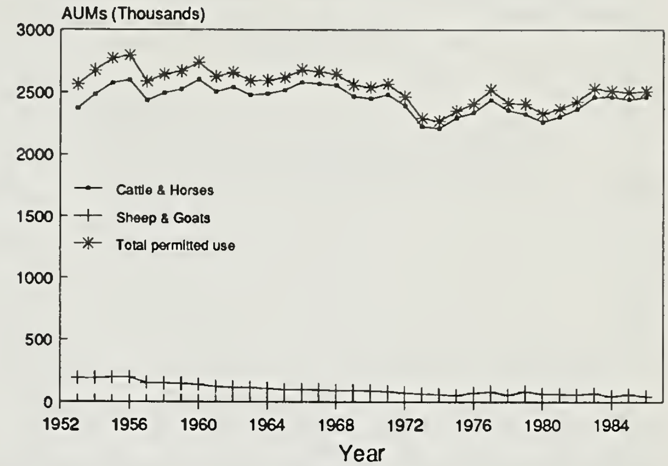


NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

Source: USDI, Bureau of Land Management (1969-1987)

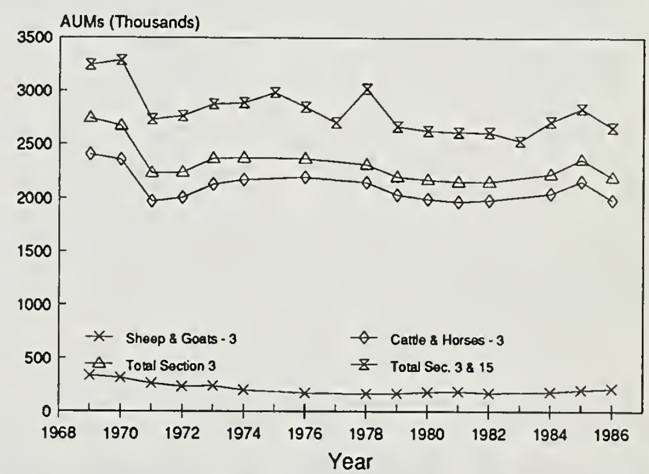
Figure 29.—Northern Rocky Mountain region grazing use.

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

Source: USDI, Bureau of Land Management (1969-1987)

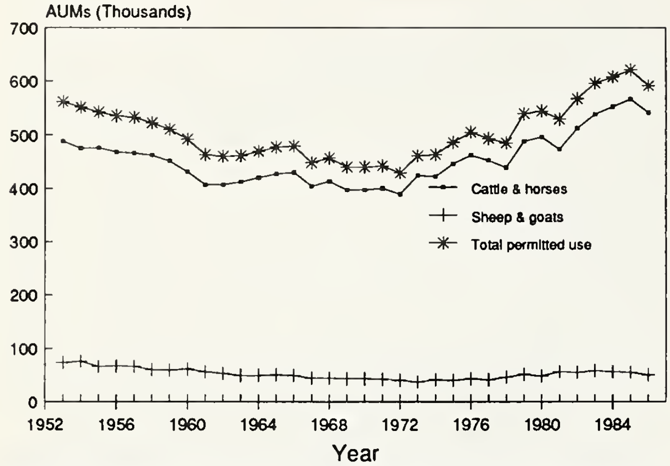
Figure 30.—Southwest region grazing use.

The NR region accounts for nearly half of the national BLM AUMs. Data available from 1969 to 1986 indicate a decline from nearly 9 million AUMs permitted in 1969 to less than 8 million in 1986 (fig. 29b). Although a breakdown of sheep and cattle AUMs on Section 15 lands over time was not available, AUMs for cattle and sheep on BLM section 3 lands reflect the trends shown for NFS lands within this region (fig. 29). Sheep use has declined nearly 50%, resulting in 1 million fewer AUMs for sheep on BLM lands by 1986.

In the Southwest (SW) region, 85% of the land under all ownerships is rangeland and livestock grazing is estimated to occur on 90% of this land. Grassland, woodland, and forest ecosystems comprise the suitable grazinglands; 46% occurs in woodland ecosystems. About 45% of the NFS permittees graze livestock yearlong on NFS lands (USDA Forest Service 1983a). Cattle comprise the major use of NFS grazing in this region. Permitted AUMs on NFS lands in the SW region have fluctuated around 2.5 million since the late 1950s (fig. 30a), even though regionally, cattle inventories increased 66% in the early parts of this period. Sheep and goat use on NFS lands has declined since 1953. Permitted grazing on BLM lands in the Southwest has declined from over 3.2 million AUMs in 1969 to less than 3 million in 1986 (fig. 30b). As on NFS lands, cattle comprise the major use and sheep and goat use have declined.

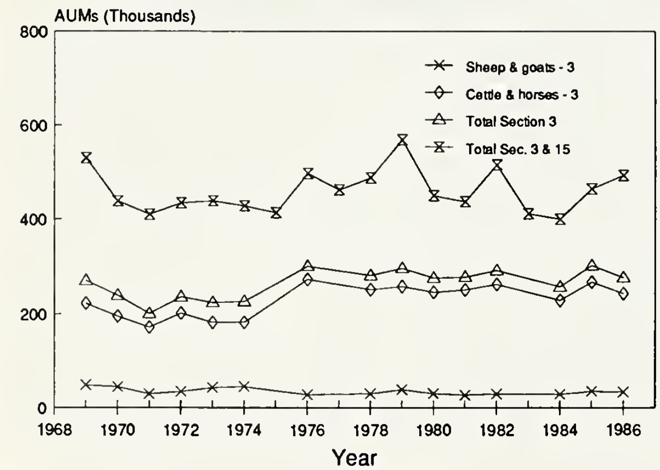
In the CA region, grazing patterns differ for the two agencies. Permitted AUMs were higher in California on NFS lands in 1984 than in 1953 (fig. 31a). The rise in total AUMs on public lands lags the rise in cattle numbers. As a percentage of the total AUMs, cattle grazing is the primary use of NFS grazinglands. Permitted sheep use

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands

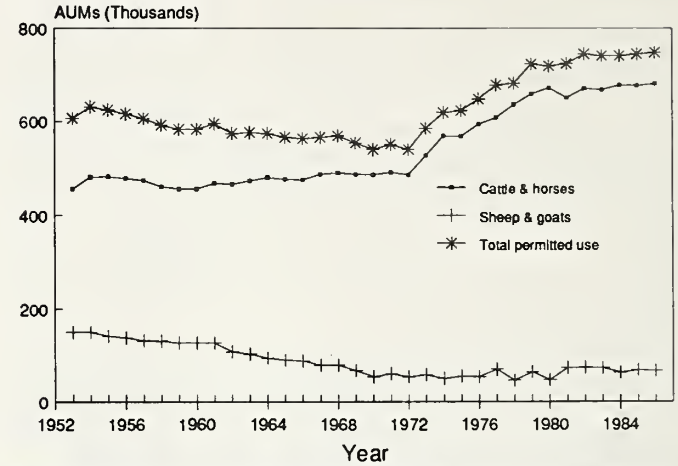


NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

Source: USDI, Bureau of Land Management (1969-1987)

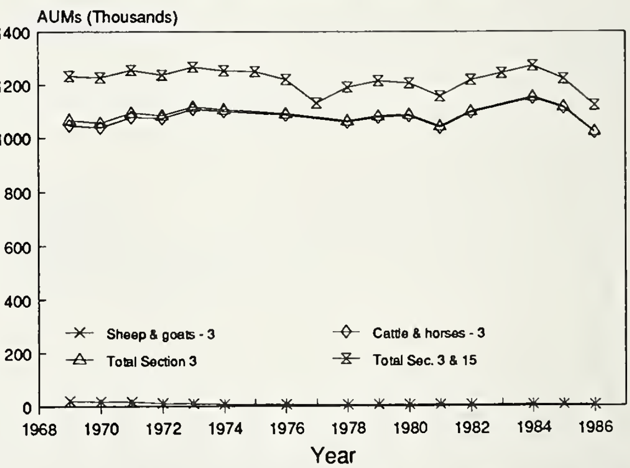
Figure 31.—California region grazing use.

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

Source: USDI, Bureau of Land Management (1969-1987)

Figure 32.—Pacific North region grazing use.

has declined on NFS lands. Use on BLM lands in California is the smallest for all western regions. Total permitted grazing since 1969 has fluctuated greatly, largely because of ephemeral precipitation in the southern part of this region (fig. 31b). On Section 3 lands, sheep and goat AUMs have remained fairly constant, but cattle AUMs have continually increased over the period (fig. 31b).

As in other western regions, grazing on public lands in the Pacific North (PN) region is important in completing the year-long feed mix within livestock enterprises. More than 80% of the grazing lands on NFS lands are forested (USDA Forest Service 1984c). Unlike trends seen in other regions, AUMs on public lands in the PN region have either increased (NFS lands) or fluctuated slightly around the same number since 1969 (BLM lands) (fig. 32). Permitted AUMs on NFS lands have increased since 1953, the result of a nearly 30% increase in cattle AUMs. Permitted sheep use has declined substantially, paralleling the regional decrease in sheep numbers. Actual use on BLM lands has remained fairly constant since 1969 (fig. 32b). Cattle AUMs on Section 3 lands have remained fairly constant while sheep AUMs, which were a small component of BLM grazing have declined since 1969.

Only 12.5 million acres, or 3.9% of the total acres, of forest and rangeland in the SO region are on NFS lands. Of these lands, only 2 million acres are considered suitable for grazing. Thus, NFS permitted AUMs in the SO region are the lowest of all regions (fig. 33a). Only 38,000 acres of NFS lands are in vegetation types such as grassland, prairie, wet grassland, and savannah (USDA Forest Service 1984d). More grazing opportunities on southern national forests occur in regeneration areas and openings within longleaf pine and loblolly-shortleaf pine ecosystems. Although these permitted numbers represent an estimate of supply, it is important to note that additional grazing opportunities could be provided

on southern national forest lands (USDA Forest Service 1984d). The decline or break in the historical trends in the SO and NO regions is the result of grazing management operations shifting to a grazing permit system in the mid-1960s (Rowley 1986). Before this point, only approximate estimates of the grazing on these forests are available.

Although NFS lands comprise over 6 million acres in the NO region, only 880 thousand acres (14%) is considered to be suitable for livestock grazing (USDA Forest Service 1981b). As in the South, grazing opportunities are primarily forest openings or regeneration sites. Grazing on NFS lands in the NO region declined between 1953 and 1965 (fig. 33b). Cattle grazing, either dairy or beef, dominates the grazing use in this region. Sheep use is very small (3,000 AUMs). The BLM does not administer any grazing within the NO or SO regions.

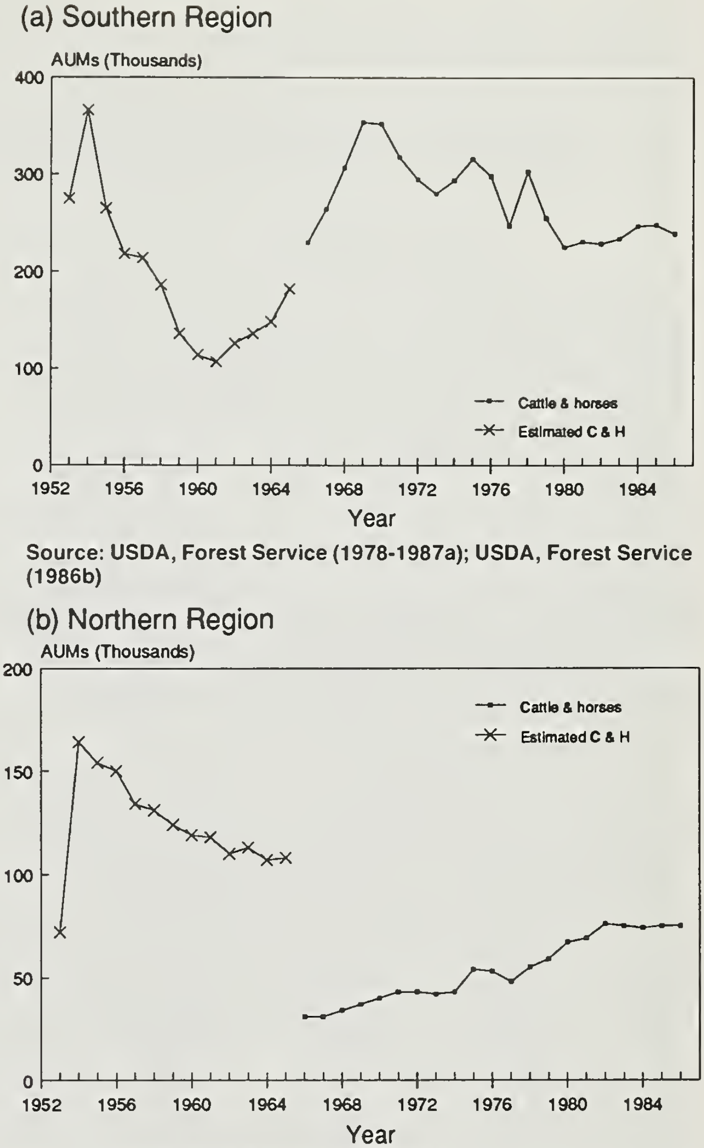
SUMMARY

Forage, that part of vegetation that is available for consumption by wild and domestic herbivores, is produced on forest land, rangeland, pasture, hayland, cropland (after crop harvest), and cropland used for pasture. Management results are influenced by the ecology of forest and range ecosystems. Past and current uses such as grazing, timber harvesting, mining, cropping and abandonment of cropland, and species introduction, have and will continue to have an affect on production from these lands. New technology, and eventually biotechnology, offers possibilities to enhance the future productivity of forest and rangelands. Economic factors, however, affect the implementation of range management technology, and the highest implementation rates have occurred for practices requiring minimal capital investment.

The management of forest and rangelands, government agricultural programs, and the environment interact to influence changes in land use across the United States. The availability of land for forage production for wild or domestic herbivores is a function of the demand for land for other uses. Conversion of forest and rangeland to a nonrevertible use such as urbanland decreases the land available for forage production and for wildlife habitat. Crop prices, the demand for cropland, government programs aimed at reducing crop surpluses, and variation in acres of crops planted influence the amount of forage supplied by cropland, the conversion of rangeland to cropland, and the price of rangeland. At times, conversion of rangeland to cropland has been high, prompting legislation to regulate the flow of highly erodible land into crop production. Conditions favorable for rangeland and forest land conversion to cropland are not likely to reoccur in the immediate future because of the following factors: (1) less favorable cost/price relationships, (2) Food Security Act of 1985, and (3) changes in the federal tax code.

The supply of forage from public lands is set by multiple resource management objectives and public policy. Recent legislation has emphasized the multiple use of federal lands, the need to examine potential impacts of management, the management of wild horses and burros, and resource planning on federal lands. Thus, the quantity of forage produced on public lands will be a function of multiresource management for wild and domestic grazing animals such as livestock, wildlife, and wild horses and burros, and other resource outputs such as timber, water, recreation, and scenic beauty. Multiresource management requires a consideration of the tradeoffs in resource production.

Assessing the forage produced nationally is difficult because forage production is not inventoried. Use, not production, is quantified when forage consumption estimates are derived from herbivore inventories. Projections of forage production will be derived from projections of the likely future technological improvements in forage production, and projections of land available for forage production. These projections, based on factors discussed here, are presented in Chapter 4.



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

NOTE.—Sheep use is about 3,000 AUMs

Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

Figure 33.—Grazing use on eastern National Forest System lands.

CHAPTER 3: FACTORS AFFECTING THE DEMAND FOR RANGE FORAGE

INTRODUCTION

Demand is defined as the quantity of product willingly bought per unit of time at a specific price[11] (Workman 1986). Less than 10% of forage consumed by livestock is leased or sold in an observable market (table 10). The price of forage from Forest Service (FS) land and on Bureau of Land Management (BLM) administered land is set by federal law. The price for forage from private lands is not usually determined by competitive bidding within a market system because this forage is often produced within the farm or ranch enterprise. Forage for wild herbivores is not usually priced in a market. Without an observable market for most of the forage consumed, the national demand for forage is difficult to analyze in terms of the traditional supply/demand equilibrium analysis of commodities as described for beef by Workman (1986).

Forage produced on forest and rangelands is intermediate to the production of the final output, such as wildlife, livestock, wild horses and burros (Bartlett 1986). The demand for the final output, the herbivore, can be used to derive the future demand for range forage. Forest and rangelands also provide other commodity outputs and noncommodity outputs (chapter 1). The management of forest and rangelands must be responsive to the demand for forage and the demand for other range outputs. Research is needed to determine the value of range vegetation in the production of these outputs (Bartlett 1986), and to develop a method for allocating the range resource across these demands (Broken and McCarl 1984).

The present chapter addresses the factors that affect the demand of range forage as derived from the demand for domestic herbivores. The demand for livestock is a function of society's demand for market commodities such as meat, hides, wool, tallow, and secondary products such as pharmaceuticals (Council for Agricultural Science and Technology 1986, USDA Forest Service 1980). About 78% of the gross income from sheep and lamb is attributed to meat, primarily lamb, with the remaining income from the sale of wool. In 1982, 73% of the cash receipts from the sale of all meat animals were from marketing cattle and calves (Nelson 1984).

Forage demand for livestock production depends on the technology associated with livestock production, the prices of alternative feeds, the total feed mix, and the price of livestock. The price of beef cattle or sheep depends upon the interactions between the supply and the demand of meat. The supply of meat is determined by the cost structure of production. The demand for meat is a function of export demand and domestic consumption. The demand for beef or lamb meat is related to consumer tastes and preferences, disposable income, changes in human population size and age distribution, and the relative prices of alternative foods, particularly other meats.

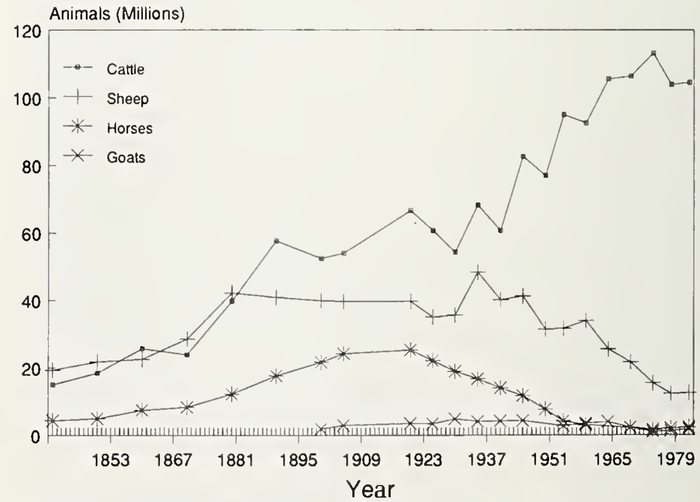
The demand for wild herbivores is a function of society's demand for nonconsumptive recreation, such as nature walks, and consumptive recreation such as hunting. Society's desire for recreational experiences associated with wild herbivores has increased the value of these grazing animals. Meeting the forage requirements of livestock and wildlife is an important management objective on public and private lands. Projections of the future demand for wild herbivores, made by Flather and Hoekstra (in press), are compared with this report's projections for domestic herbivores in Chapter 5.

[11] *This assumes all other prices, population, income, tastes, preferences, and any other factors that might affect quantity demanded are held constant.*

LIVESTOCK PRODUCTION IN THE UNITED STATES

Historical Livestock Numbers at the National Level

Cattle and sheep inventories were nearly equal in 1840 and both animal types increased until 1880 when sheep inventories leveled off (fig. 34). Cattle numbers continued to increase until 1975 when inventories reached



NOTE.--Only source of consistent data for all animal types: latest census: 1982.

Source: USDC, Bureau of Census (1935-1982)

Figure 34.—Number of livestock on farms in the United States.

their historical peak and began to decline. Sheep numbers peaked in the mid-1930s at about 56 million head and have since dropped to 10 million head in 1986 (USDA 1987). Horse numbers increased with the westward expansion of agriculture to a peak of 20 million in the 1920s. At this time the tractor was introduced, and mechanical power gradually replaced horses. In 1982, horse inventories were around 2 million animals on farms, or 5 million if the growing numbers of recreational animals are included. Goat inventories have historically been small compared with other grazing animals (fig. 34). In 1984, about 1.5 million goats were reported in the United States, mostly in Texas (USDA Statistical Reporting Service 1985).

Historical Livestock Numbers at the Regional Level

Cattle numbers in western regions increased from 17% to 35% over 1955 numbers (table 16). Sheep numbers dropped to levels ranging from 37% to 51% of the 1955 inventories. In the Northern Rocky Mountain (NR) region, cattle numbers rose continually until they peaked in 1974 at 34 million (table 16). By 1986, cattle numbers were at only 79% of the 1974 peak but 117% of the 1955 level. Sheep inventories rose to 11 million animals in 1959 and declined thereafter. By 1986, sheep numbers were 34% of the 1955 inventory in the NR region. In the Southwest (SW) region, cattle numbers increased nearly 66% between 1955 and 1973 to 3.0 million, and then declined to 2.4 million by 1986 (table 16). Southwestern sheep numbers have declined since 1955 and in 1986 were less than 50% of the 1955 inventory. Cattle inventories within the California (CA) region have sustained the greatest increase of all western regions, 138% of the 1955 inventory in 1986 (table 16). Sheep numbers have followed the national trend. Cattle numbers in the Pacific North (PN) region have increased since 1955; sustained declines occurring only since 1980. Sheep numbers in the PN region have paralleled the national trend.

Cattle numbers in the eastern regions (Northern and Southern) rose only 4% from 1955 to 1986, whereas sheep numbers declined 75% (table 17). In contrast to national increases between 1955 and 1974, cattle numbers in the Northern (NO) region remained fairly constant, a reflection of this region's dairy industry. After

Table 16.—Livestock numbers (1,000 head) in the western United States by assessment region.

Year	Northern Rocky		Southwest		California		Pacific North	
	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
1955	22,927	9,904	2,147	1,627	3,863	1,700	2,646	1,105
1956	23,158	9,912	2,234	1,581	3,863	1,700	2,674	1,075
1957	21,346	9,906	2,087	1,587	3,870	1,632	2,520	1,080
1958	21,887	10,827	1,999	1,591	3,733	1,616	2,545	1,095
1959	23,071	11,103	2,133	1,647	4,044	1,600	2,675	1,146
1960	24,144	10,742	2,377	1,743	4,274	1,712	2,824	1,185
1961	23,071	10,440	2,221	1,606	4,207	1,763	2,643	1,150
1962	23,796	10,157	2,262	1,583	4,232	1,657	2,703	1,082
1963	25,631	10,190	2,339	1,550	4,778	1,541	2,835	1,004
1964	27,234	9,850	2,341	1,515	4,902	1,526	2,963	953
1965	27,397	9,344	2,246	1,420	4,913	1,511	3,054	859
1966	28,122	9,173	2,244	1,434	5,022	1,511	2,917	838
1967	28,729	9,292	2,489	1,315	5,119	1,412	2,947	667
1968	28,837	8,336	2,506	1,237	5,168	1,370	2,931	632
1969	29,007	7,849	2,552	1,227	5,140	1,234	2,863	613
1970	29,733	7,518	2,688	1,215	5,107	1,185	2,853	574
1971	31,036	7,252	2,661	1,192	5,020	1,149	2,894	544
1972	31,954	7,066	2,804	1,122	4,907	1,011	2,891	530
1973	32,477	6,681	3,035	1,084	4,952	956	2,903	491
1974	34,281	6,349	3,005	1,057	5,490	980	2,850	477
1975	32,997	5,626	2,890	930	5,450	910	2,890	432
1976	31,313	5,028	2,930	927	5,245	870	2,875	402
1977	29,675	4,483	2,565	910	4,990	900	2,870	374
1978	28,919	4,270	2,685	924	4,664	915	2,765	366
1979	28,634	4,162	2,700	935	4,915	965	2,850	406
1980	28,865	4,021	2,650	935	4,763	1,000	3,154	435
1981	29,905	4,178	2,475	920	4,980	1,030	3,200	500
1982	29,935	4,536	2,500	915	5,228	1,010	3,380	543
1983	30,165	4,526	2,450	858	5,130	920	3,220	450
1984	30,340	4,041	2,370	786	5,226	900	3,360	412
1985	28,695	3,962	2,460	718	5,181	870	3,120	398
1986	26,975	3,459	2,440	686	5,209	860	3,035	383

Source: U.S. Department of Agriculture (1955-1987), Agricultural Statistics.

Table 17.—Livestock numbers (1,000 head) in the eastern United States by assessment region.

Year	Northern		Southern	
	Cattle	Sheep	Cattle	Sheep
1955	35,646	5,778	29,363	7,114
1956	36,079	5,832	29,457	6,871
1957	36,013	5,919	28,666	6,414
1958	35,371	6,204	28,432	6,670
1959	35,482	6,198	29,245	7,135
1960	36,715	6,146	31,186	7,688
1961	35,405	5,689	29,772	7,469
1962	36,013	5,535	30,494	6,961
1963	36,549	4,945	31,596	6,485
1964	36,589	4,553	32,451	6,118
1965	36,765	4,558	32,801	5,549
1966	35,340	4,264	32,884	5,874
1967	35,084	3,722	34,269	5,263
1968	34,545	3,501	34,817	4,595
1969	34,491	3,378	35,823	4,347
1970	34,784	3,249	37,129	3,932
1971	34,918	3,092	37,932	3,988
1972	35,643	2,678	39,654	3,560
1973	35,961	2,522	42,197	3,278
1974	37,180	2,271	44,855	3,193
1975	38,278	2,023	49,312	2,904
1976	38,360	1,800	47,248	2,804
1977	37,172	1,899	45,530	2,676
1978	35,574	1,765	41,760	2,637
1979	33,611	1,766	38,145	2,545
1980	33,807	1,798	37,945	2,540
1981	34,533	1,847	39,220	2,446
1982	34,492	1,958	40,060	2,613
1983	33,780	1,688	40,445	2,347
1984	32,646	1,584	39,949	2,056
1985	31,655	1,485	38,598	1,914
1986	30,425	1,405	37,375	1,939

Source: U.S. Department of Agriculture (1955-1987), Agricultural Statistics. NOTE: Oklahoma and Texas are included in the Southern region.

1976, however, cattle numbers followed the national decline, dropping from 38 million to 30 million in 1986. Sheep numbers in the NO region also reflected the national trend. In 1955, cattle numbers in the Southern (SO) region were only 82% of cattle inventories in the NO region (table 17). By 1986, cattle inventories were greater in the South than the North. A continuous decline in southern sheep inventories has occurred since 1955 (table 17).

The largest inventories of cattle are in the NR region, the NO region, and the SO region (tables 16 and 17). The 17 western states support more than 80% of the Nation's sheep inventory (Council for Agricultural Science and Technology 1982). About 20% of the nation's sheep herd is in Texas. Large sheep inventories are also in California, Wyoming, South Dakota, Utah, New Mexico, Montana, and Colorado. Between 1960 and 1982, sheep production in the western regions rose from 75% to 82% of the national total. This shift from east to west may be related to the conversion of pasture land to crop production in the east and a trend toward agricultural specialization (Gee and Madsen 1988).

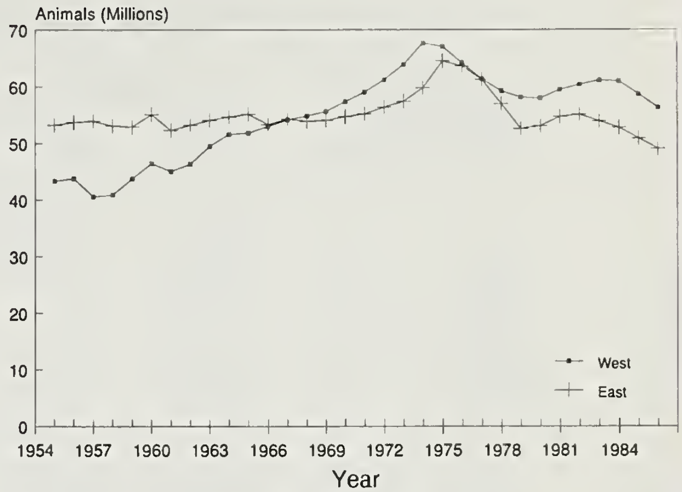
Cattle Cycles

Cycles in cattle inventories are initiated when producers, responding to rising economic indicators such as cattle prices, build up their herds. Because producers must wait nearly 3 years from the time a heifer is bred until its calf is old enough to enter the breeding herd (Gilliam 1984), the expansion part of the cycle (cattle numbers increasing) lasts from 5 to 6 years. Forage demands increase during this part of the cattle cycle. With greater cattle supply, prices begin to decline, and the producers begin to liquidate their herds until supply is low and prices begin to rise. The cycle commences again.

The last two cycles, starting in 1967 and in 1980, have not followed the dynamics of previous cycles (Gustafson 1983). Cattle numbers in the 1967-79 cycle peaked in 1975 at over 130 million head. By 1979, cattle numbers had dropped 21 million head, a 16% decline. Herd expansion in the next cycle added only 4.6 million head to the national inventory. Unlike previous cycles, this expansion did not increase the national herd over historic levels (fig. 34). Inventory on January 1, 1987 was 102 million head, 21% lower than 1975 levels.

These recent aberrations in the cattle cycle may be the result of several factors. The rise during the 1967-79 cycle reflected an expanding forage base from highly productive cropland shifting to cropland pasture and increased use of cheap fertilizer (Gustafson 1983). The rapid cattle decline coincided with rising grain prices, rising energy prices, and land shifting back into crop production. Herd expansion during the 1980 cycle was small, reflecting the agricultural financial crisis, and record high total meat supplies (Gustafson 1983). Bobst and Davis (1987) estimated that each million acre addition in harvested cropland (cropland expansion implied a decrease in pasture) was associated with a decline of nearly 37,000 beef cows.

In terms of forage supplies, the dynamics of these cattle numbers give an indication of the forage potential within the cattle production system. Eastern livestock operations are more closely associated with crop production than livestock operations in western United States (Gilliam 1984). Thus, the changes in land used for crops in the eastern United States will impact the forage available for grazing animals. A comparison of livestock numbers in the West (all western assessment regions plus Oklahoma and Texas), and in the East (NO and SO regions minus Oklahoma and Texas) indicates a shift of livestock production from eastern to western regions over 1955-86 (fig. 35). Livestock production in the West expanded much more rapidly than in the East. National cattle numbers have declined 21% between 1975 and 1986, but the decline has been much greater in the East (24%) than in the West (17%). Although a decline might indicate a surplus of grazed roughages in the Nation's cattle production system, the decline in the East may be more related to shifts in cropland use from pasture to crop production (Gustafson 1983). The decline in the West, which also represents a shift from cropland pasture to crop production, may be truly representative of a surplus in forage, as much of the land grazed is forest and rangelands and not suitable for cropland.



NOTE.--East: NO and SO regions except Oklahoma and Texas;
West: all other regions and Oklahoma and Texas.
Source: USDA (1955-1986)

Figure 35.—Number of cattle in the eastern and in the western United States, 1955-1985.

FORAGE CONSUMPTION

National and Regional Forage Consumption by Livestock

Beef cattle and sheep represent the largest inventories of livestock that use grazed roughages in the United States. Dairy cattle make up a small part of the national inventory, and, since 1985, have declined further in response to the legislated dairy herd reduction program. Harvested forages, such as hay, and concentrate provide most of their diet. Gee and Madsen (1988) estimated that the annual consumption of grazed roughages by goats is about 3.6 million AUMs, a small amount nationally when compared with the consumption of 431 million AUMs by beef cattle and sheep (table 10). The demand for grazed forages by the 2 million farm horses is also small in comparison to beef cattle. The feed demand by horses, including recreational horses, could potentially be greater than the demand by sheep. The feed sources for recreational horses, however, are primarily purchased hay. Some hog production systems use pasture, but USDA Economic Research Service (1985) reported that less than 1% of hog feed costs are for pasture. Smith et al. (1980) estimated that hogs and horses consumed less than 3% of the total nutrients supplied by forages nationwide. Because the combined total demand for grazed forage by dairy cattle, goats, and horses is small compared with beef cattle and sheep, the consumption of grazed forages is analyzed only for beef cattle and sheep in this assessment.

The main sources of forage consumed by beef cattle and sheep are deeded nonirrigated rangeland and pasture, publicly owned grazing land (i.e., federal, state, local governments), deeded irrigated pasture, and crop residues. Although the importance of enterprise-owned land is evident in that this source provides over 70% of forage consumed by beef cattle and sheep (table 10), other sources may represent the only available forage during certain seasons of the year. The regional combinations of deeded land with other forage sources (table 18) is a function of the availability of other sources, the local environment, and the type of livestock operation. The large relative contribution of public grazing in the SW and the NR regions is a reflection of the extensive amount of public land in those regions (table 5). Because of the availability of public forage, a ranch may raise hay on private land to support the livestock during the winter. The regional significance of crop production as a land use is seen in the NO region (fig. 8) where crop residues are the only source, other than deeded land, associated with beef cattle operations (table 18). The availability of irrigation in the CA and the PN regions is evidenced by the importance of irrigated pasture here in contrast to other regions. Although irrigation is available in the SW region, specialty crops bring a higher return than irrigated pasture.

Table 18.—Consumption of grazed forages by beef cattle and sheep on an animal unit month (AUM) basis, 1985.

Region	Deeded non irrigated		Public grazing		Irrigated grazing		Crop residue		Total
	Thousand AUMs	Percent	Thousand AUMs	Percent	Thousand AUMs	Percent	Thousand AUMs	Percent	Thousand AUMs
					Beef Cattle				
PN	9,929	74	611	5	2,162	16	671	5	13,373
CA	12,118	79	1,048	7	1,702	11	498	3	15,367
SW	8,310	64	4,448	34	88	1	109	1	12,956
NR	95,746	81	11,452	10	3,804	3	7,777	6	118,780
NO	66,118	94	—	—	—	—	3,926	6	70,044
SO	167,137	92	6,603	4	801	T[1]	7,030	4	181,571
Total	359,359	87	24,163	6	8,557	2	20,011	5	412,090
					Sheep				
PN	254	31	466	57	41	5	57	7	818
CA	1,055	52	183	9	203	10	589	29	2,029
SW	838	59	298	21	100	7	185	13	1,421
NR	2,369	31	4,356	57	382	5	535	7	7,642
NO	2,184	70	—	—	—	—	936	30	3,120
SO	4,042	100	—	—	—	—	—	—	4,042
Total	10,742	56	5,304	28	725	4	2,302	12	19,073
					Beef Cattle and Sheep				
PN	10,182	72	1,078	8	2,203	16	729	5	14,191
CA	13,174	76	1,230	7	1,905	11	1,087	6	17,369
SW	9,148	64	4,747	33	188	1	294	2	14,376
NR	98,116	76	15,809	13	4,186	3	8,312	7	126,422
NO	68,303	93	—	—	—	—	4,862	7	73,165
SO	171,179	92	6,603	4	801	T	7,030	4	185,612
Total	370,101	86	29,466	7	9,283	2	22,312	5	431,163

Note: Totals may not add up as a result of rounding.
[1]*T = Less than 1%*
Source: Gee and Madsen (1988).

Crop residue, irrigated pasture, and public grazing supply a greater share of the feed mix for sheep than for cattle (table 18). Nationally, public grazing land contributes 28% of the total feed mix for sheep, whereas this is only 6% of the total feed mix for beef cattle. In the PN, and the NR regions, public grazing contributes more than 50% of the total feed mix for sheep whereas deeded non-irrigated land contributes only 30%. Nationally, crop residue contributes 12% to the total feed mix for sheep, but only 5% for beef cattle.

Total forage consumption estimates based on ranch/farm surveys (table 18) are compared with estimated feed requirements based on national livestock inventories (table 19). Over 670 million AUMs are needed to meet the total feed requirement of beef cattle (excluding cattle in commercial feedlots) (table 19). Based on the ranch budgets, 61% of this total feed requirement, or 431 million AUMs, is met by grazed forages (table 18). For sheep (excluding lambs in feedlots), 90% of the annual feed requirements are met with grazed forages (table 19). These percentages of the total feed mix supplied by grazed forages appear reasonable, given the distribution of livestock operations in the United States (Gee and Madsen 1988). Few areas have large beef cattle inventories and 12 months of grazed forages available, implying that a certain percentage of the cattle diet will need to be met with harvested forages or concentrates. In many areas, grazing is limited to 6 or 7 months because of adverse climatic conditions (Gee and Madsen 1988). Sheep are more dependent on grazed forages than cattle. Little supplementary feed is used in the production of sheep in the 17 western states with the exception of several months in the Northern Great Plains (Gee and Madsen 1988). These grazed forage estimates (table 18) form the basis for an examination of the regional distribution of grazed forages by livestock type, and the future demand of forage by livestock type.

Use of Livestock Forage on Public Lands

Permitted AUMs represent the amount of forage available for livestock grazing on public lands and were given as an estimate of the supply of forage from public lands (Chapter 2). Livestock are authorized to graze an allotment under a grazing permit, grazing agreement, livestock use permit, or other authorizing document. Annually, only about 1% of the grazing allotments on National Forest System (NFS) and BLM-administered lands are vacant (without a grazing agreement with a

Table 19.—January 1 inventory (1,000 head) of and estimated feed requirements (1,000 units) for beef cattle and sheep in the United States, 1985.

Livestock	Inventory	Animal units[1]	Animal unit months
Beef cattle:			
Cows that have calved	35,393	44,949	
Replacement heifers	6,183	3,833	
Steers 500 pounds and over[2]	6,560	4,067	
Bulls	2,411	3,014	
Total cattle		55,863	670,356
Sheep:			
Stock sheep 1 year and older			
Ewes	7,233	1,447	
Rams and wethers	314	63	
Stock sheep, lambs			
Ewes	1,016	203	
Rams and wethers	284	57	
Total sheep		1,771	21,252
Total cattle and sheep			691,608

[1]*Conversions to animal units are cows, 1.27; yearlings, 0.62; and bulls, 1.25. All sheep have the same animal unit value and five head equals one animal unit.*

[2]*Assumes 30% of steers in January inventory used grazed forages. The remainder went to feedlots for finishing.*

Source: Gee and Madsen (1988).

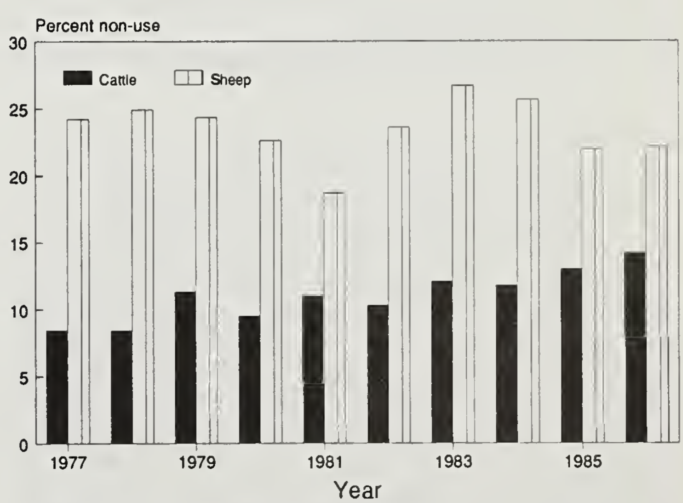
permittee) (USDA Forest Service and USDI Bureau of Land Management 1986). Most of these vacant allotments are high-elevation sheep allotments for which demand has declined because of remoteness, cost of operation, labor shortages, and the decline in the sheep industry. A permittee may elect to take non-use on an allotment. Non-use is an authorization to refrain from grazing livestock without the loss of preference for further consideration (USDA Forest Service and USDA Bureau of Land Management 1986). One indication of the demand for forage is the trend of those AUMs in non-use on NFS lands.[12]

Cattle non-use on NFS lands increased from less than 10% in 1977 to 14% in 1986 (fig. 36). Although permitted use on NFS lands has remained fairly constant from 1980 to 1986 (figs. 28-33), this increasing non-use reflects the general economic decline in the agricultural sector. This 1977-86 period coincided with the continual decline in the national cattle herd (fig. 34).

Sheep non-use fluctuated from a high of 26% to a low of 19%; no definite trend occurred in 1977-86. Although the sheep non-use percentage is higher than the cattle non-use, in terms of AUMs, this percentage represents a much smaller number of AUMs than cattle non-use. In 1980, total AUMs for sheep and goats (authorized to graze) were 1.1 million in contrast to the 8.5 million AUMs for cattle.

Regional trends of total non-use AUMs (cattle, horses, sheep, and goats) show a slight increase since 1977, reflecting the dominance of cattle AUMs. Trends in non-use are similar across the western regions (NR, PN, CA, SW), increasing from 10% in 1977 to about 15% in 1986 (fig. 37). Non-use in the eastern regions (NO and SO) was higher than in the western regions (fig. 37), perhaps reflecting the increased emphasis of crop production in the eastern regions.

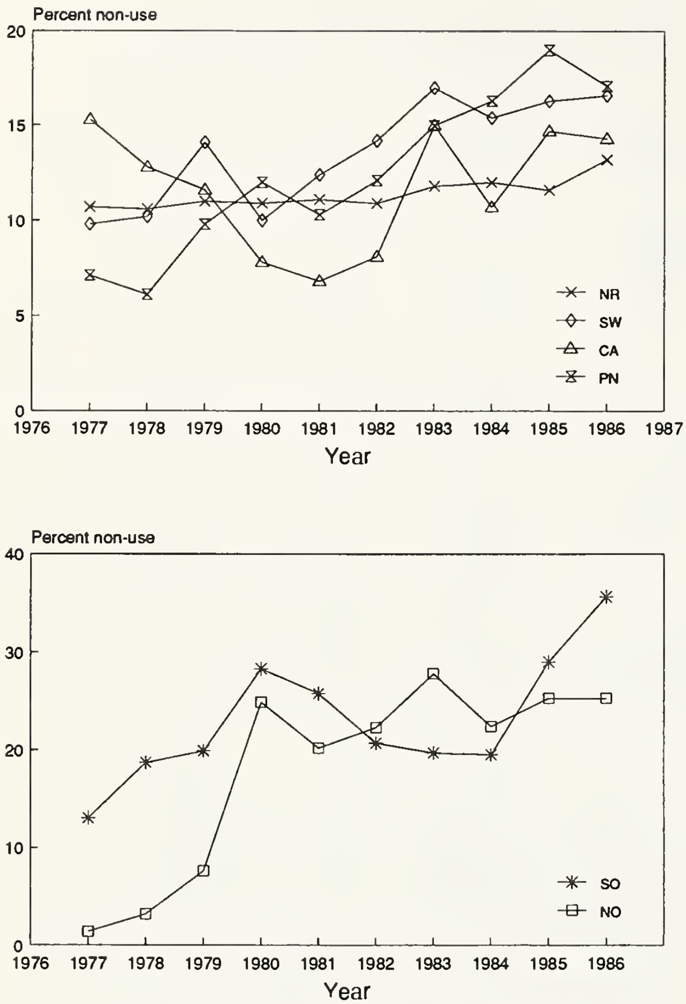
[12]*For this study, non-use percent is calculated as [1 – Actually grazed Paid Permits / Authorized to Graze] times 100 from data in the Annual Grazing Reprts of the Forest Service. No data was available for the BLM.*



NOTE.--Non-use = [1-(actually grazed paid/authorized use)].

Source: USDA, Forest Service (1978-1987)a

Figure 36.—Non-use of cattle and sheep permitted use on National Forest System lands.

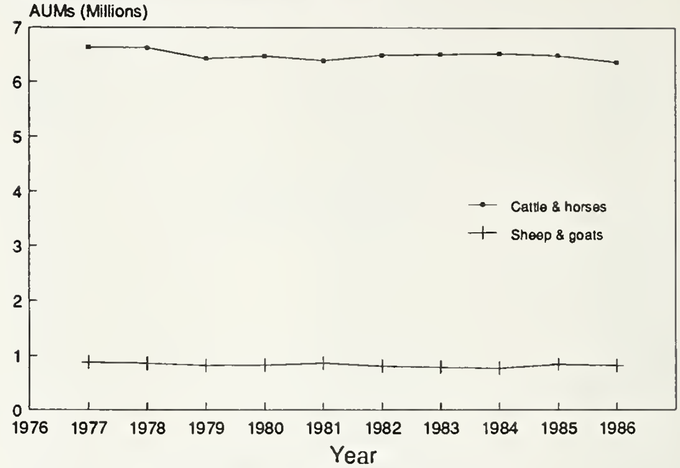


NOTE.--Non-use = [1-(actually grazed paid/authorized use)].

Source: USDA, Forest Service (1978-1987a)

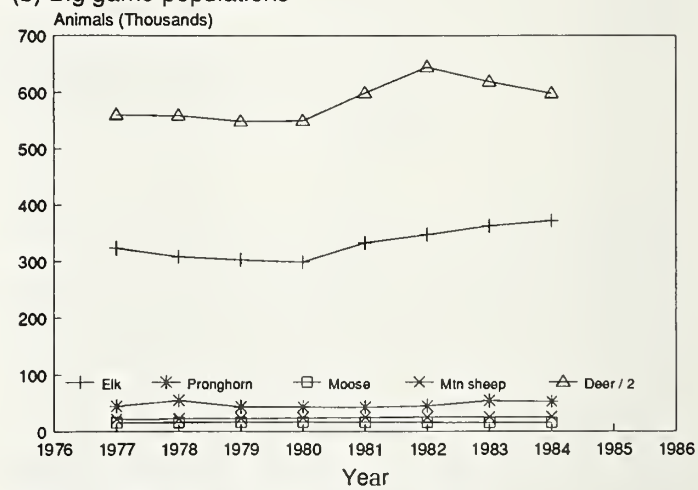
Figure 37.—Non-use as a percentage of authorized grazing on NFS lands by assessment regions.

(a) Paid permitted livestock use



Source: USDA, Forest Service (1978-1987a)

(b) Big game populations



NOTE.--Wildlife data only available to 1984.
Mountain sheep includes bighorn sheep and mountain goats.

Source: USDA, Forest Service (1978-1987b)

Figure 38.—Large herbivores using National Forest System lands in the Rocky Mountain region.

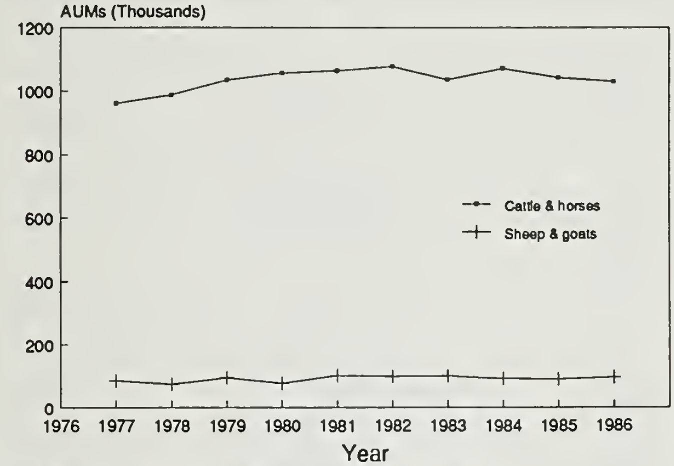
Wild Herbivore Populations and Domestic Grazing Use on National Forest System Lands

Wild and domestic herbivores graze forest and rangelands. Wildlife populations are not managed in the same manner as cattle and sheep. Livestock are managed for restricted movement, whereas wild herbivores migrate across the landscape in response to habitat, food, and water needs. Population estimates for NFS lands reflect wildlife use of those lands (Flather and Hoekstra in press, USDA Forest Service 1978-1987b), however the migratory habits of big game animals result in the use of different ownerships (surrounding private and other public lands) at different times of the year. Thus, trends in wildlife numbers reflect management from a mosaic of land ownerships. Livestock use on NFS lands is closely regulated and data on actual use by livestock (livestock actually grazed paid permitted AUMs) is reported yearly (USDA Forest Service 1978-1987a). Information was available to compare wild and domestic herbivore trends on NFS lands only.

Nationally, big game populations on NFS lands have remained stable or have increased, whereas livestock permitted AUMs have remained stable or declined since 1977 (fig. 28). Before 1977, mule and black-tailed deer populations declined across all ownerships. Domestic sheep AUMs on NFS lands have continued a steady decline (fig. 28). Big game abundance has increased most notably for moose, elk, and bighorn sheep.

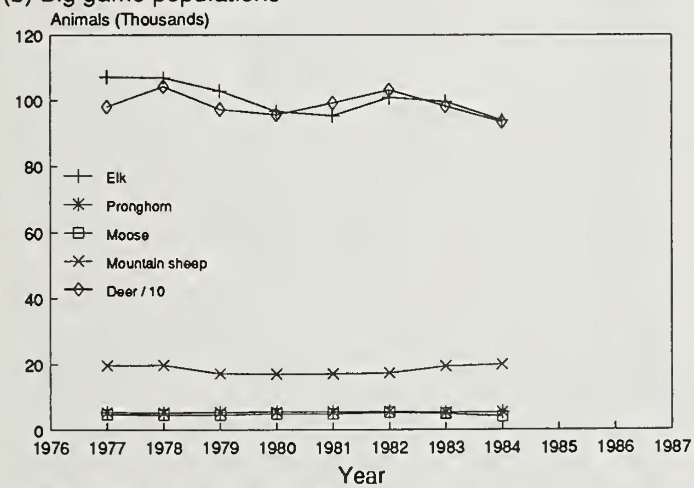
In the Rocky Mountain region (NR and SW regions), livestock actual use has declined 4%, while numbers of deer and elk have increased 6% and 15%, respectively, over 1977-86 (fig. 38). Pronghorn numbers, small relative to deer and elk, have increased 17% since 1977.

(a) Paid permitted livestock use



Source: USDA, Forest Service (1978-1987a)

(b) Big game populations

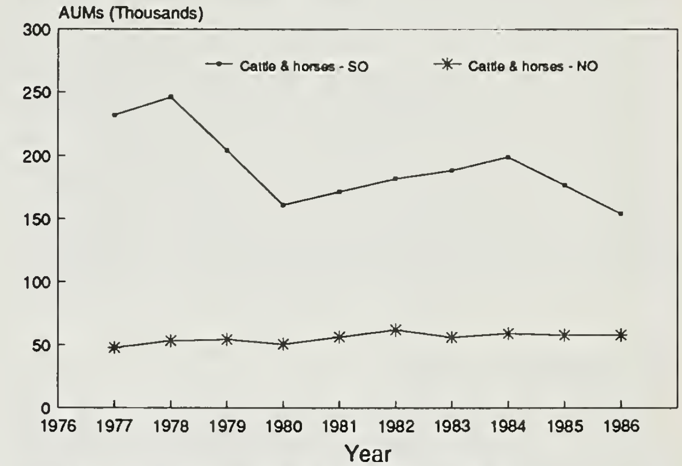


NOTE.--Wildlife data only available to 1984.
Mountain sheep includes bighorn sheep and mountain goats.

Source: USDA, Forest Service (1978-1987b)

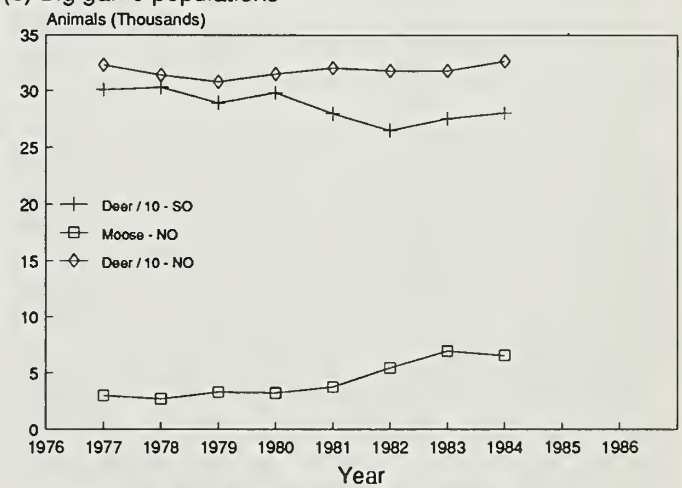
Figure 39.—Large herbivores using National Forest System lands in the Pacific Coast region.

(a) Paid permitted livestock use



Source: USDA, Forest Service (1978-1987a)

(b) Big game populations



NOTE.--Wildlife data only available to 1984.

Source: USDA, Forest Service (1978-1987b)

Figure 40.—Large herbivores using National Forest System lands in the eastern United States.

Moose numbers have remained relatively stable, while bighorn sheep numbers have increased 28% (fig. 38b).

In the Pacific Coast region (PN and CA regions), cattle and horse AUMs have increased 7% over the 1977 levels, while deer and elk numbers have declined 5% and 12%, respectively (fig. 39). The slight rise in wild mountain sheep (bighorn sheep and mountain goats) is a reflection of increases in mountain goat populations.

Large herbivore use on NFS lands in eastern United States (fig. 40) shows that in the NO region, cattle and horse AUMs have increased 21% since 1977. Domestic sheep use has declined 86%; AUMs dropped from 2 million in 1977 to 249,000 in 1986 in the NO region. Deer numbers on NFS lands have remained fairly constant, although declines in the 1970's possibly were related to declining forest land area in early successional stages (Flather and Hoekstra in press). Moose numbers have doubled in the NO region since 1977 (fig. 40b). In the SO region, livestock AUMs and deer numbers both declined in 1977-86, however the declines were greater for livestock (fig. 40). Over a longer period of time, white-tailed deer numbers appear to be stable, fluctuating between 250,000 to 300,000 animals (Flather and Hoekstra in press).

DEMAND FOR FORAGE BY LIVESTOCK

Beef Industry Structure

The availability of grazed forages is critical in two segments of the beef cattle industry: breeding herds and stocker cattle production. Little grazed forage is used in

this last segment of the beef industry, fed beef production, but this final step influences the retail product, and thus, can influence the demand for grazed forages. The objective of a beef cow-calf operation is to maintain and breed cows for the primary purpose of producing stocker calves and yearlings. Most stocker cattle enterprises seek to produce animals of weight and condition that will go easily into a finishing program upon entering commercial feedlots (Gee and Madsen 1988). Although some stocker cattle are slaughtered, most stocker cattle are placed in feedlots and fed grain and concentrates before slaughter.

Breeding Herds

Based on January 1 inventory numbers, the breeding herds are primarily in the SO (46% of the total), the NR (28%), and the NO (19%) regions (table 20). This regional distribution has changed little from 1978 to 1986. The largest increase in cow numbers was in the NR region with over 1 million additional cows and the largest decrease was in the NO region with about 500,000 fewer cows (Boykin et al. 1980, U.S. Department of Agriculture [various years]).

Nationally, less than 50% of all beef cows are in herds of more than 100 cows. Within the northeastern United States, small herds of less than 20 cows make up more than 50% of the total cow inventory, whereas in the western regions, less than 6% of the cow inventory is in small herds (Gilliam 1984). Operations are much larger in the western regions where 30% of the beef cows are in operations of 500 or more brood cows.

The number of producers with fewer than 20 brood cows represents a greater proportion of the total number of enterprises than these herds represent in the total inventory. About 60% of the nation's cow-calf enterprises have less than 20 brood cows. The remaining 40% manage more than 80% of the total cow herd (Gilliam 1984).

The types and costs of feed in the cow-calf operation reflect the location of the operation, the mix of native and seeded vegetation available within the operation, and the accessibility to other forage sources. Brood cows must be fed year-round and feed is needed to maintain the calves until weaning or shortly thereafter when they are sold to stocker operations. Cow-calf operations normally rely on grazed forage as the primary feed source because of the relative low cost. Yet, grazing in the cow-calf operation comprises more than half of the total direct production cost (Gilliam 1984). Snow cover, drought, or poor nutritional quality during some seasons necessitate additional feed from harvested forages, such as hay or silage (Gee and Madsen 1988).

The amount of land used only for grazing (dry range and irrigated pasture) within cow-calf operations increases from eastern to western United States and as the size of the cow-calf operation increases (table 21). The importance of rangeland also increases from east to west, wherein 95% of the grazed forage is supplied from range and native pasture. In the western regions, 80% of the enterprises sell only beef cattle and less than 50% of the western operations sell any other crop, excluding hay (Gilliam 1984). Western cow-calf operations are primarily beef operations using predominantly range grazing as feed.

Small cow-calf operations generally use larger percentages of secondary sources of grazing, such as corn, grain sorghum, soybeans, and other cropland after the crops have been harvested (table 21). The relatively large acreage associated with crop residues in the North Central and Southern regions (table 21) reflects the fact that most cow-calf operations in these regions are supplemental enterprises located on farms primarily producing crops and other livestock products, such as hogs (Gilliam 1984). In some regions, crop residue grazing may represent the only forage available during that season (Gee and Madsen 1988). Thus, the significance of the feed sources is not apparent from the magnitude of feed supplied, but rather the availability of substitutes for that feed during that season.

The estimates of forage sources in table 21 do not include any public land or private grazing leased or rented. The implication of this additional feed source can be surmised in the forage diversity of western ranches where public land is more common. Ranches

Table 20.—Inventory of beef cows (1,000 head) by Assessment region in 1978 and 1986.

Region	1978 Beef cow numbers	1978 Percent of total	1986 Beef cow numbers	1986 Percent of total
California	966	2.5	1,305	3.2
Pacific North	986	2.5	1,240	3.0
Northern Rocky	10,153	26.1	11,479	28.1
Southwest	917	2.4	951	2.3
Northern	7,600	19.6	7,126	17.4
Southern	18,104	46.9	18,807	46.0
Alaska	NA	NA	4	T[1]
11 Western States	6,886	17.6	7,542	18.4
United States	38,726	100.0	40,912	100.0

[1] *Trace.*

Source: 1978 data: USDA Economic Research Service (1979). 1986 data: U.S. Department of Agriculture (1987), Agricultural Statistics.

Table 21.—Acres per cow of various forage sources grazed within beef cow-calf farms and ranches, 1980.[1]

Region and forage source	Cow herd size (head)			
	20-99	100-499	500 or more	All sizes
South[2]:				
Annual pasture	0.14	0.18	0.15	0.15
Seeded perennial pasture	2.05	1.68	2.15	1.96
Native pasture	0.38	1.21	2.36	0.88
Hay aftermath	0.78	0.41	0.20	0.60
Crop residue	0.38	0.09	0.03	0.25
Total	3.73	3.57	4.89	3.84
North Central:				
Annual pasture	0.04	0	0	0.03
Seeded perennial pasture	1.53	2.20	3.90	1.75
Native pasture	1.05	0.33	1.56	0.90
Hay aftermath	0.26	0.61	0.18	0.34
Crop residue	0.20	0.58	0.23	0.28
Total	3.08	3.72	5.87	3.30
Great Plains:				
Irrigated pasture	0.03	0.01	T[3]	0.02
Small grain pasture	0.01	0.02	0.40	0.07
Dry range	8.80	12.74	27.22	12.96
Hay aftermath	0.33	0.29	0.08	0.28
Crop residue	0.21	0.12	0.02	0.15
Total	9.38	13.18	27.72	13.48
West:				
Irrigated pasture	0.83	0.34	0.39	0.47
Small grain pasture	T	0	0	T
Dry range	15.08	18.59	23.93	19.34
Hay aftermath	0.80	0.54	0.53	0.60
Crop residue	0.04	0.05	T	0.03
Total	16.75	19.52	24.85	20.44

[1]*Excludes BLM and FS grazing, and grazing leased or rented from all other sources.*

[2]*These regions differ slightly from the Assessment regions: South here includes all states in Southern region except OK and TX; North Central here includes all states in Northern region except ME, NH, VT, MD, PN, NY, RI, MA, and northern parts of MI, MN, WI; Great Plains here includes ND, KS, OK, TX, the eastern parts of SD and NE, and the Front Range parts of CO, and NM; the Western region here includes all of the Western states except those parts in the Great Plains region.*

[3]*T = less than 0.005 acre.*

Source: Gilliam (1984)

in the Great Plains are more dependent on dry (native) range than western ranches. Ranches in the West are more likely to have up to 5% of their feed source from irrigated pasture (table 21). The presence of hay aftermath as a grazing source indicates that these lands can be set aside for the production of hay. Western ranches had at least 2% of their lands in hay production and, in some size classes, as much as 5%. Great Plains ranchers had lesser amounts of hay production within each size class. The availability of federal or private-leased forage increases the ranches' flexibility in determining the total feed mix for the enterprise. Any change in this availability would require substantial changes in feed production.

Although additional forage production can be obtained by improvement, such as fertilization, a 1976 survey of cow-calf producers indicated that western range is rarely fertilized. During a 1981 survey, only 8% and 19% of native pasture in the SO and NO regions, respectively, were fertilized (Gilliam 1984). Fertilization rates on seeded pasture were much higher. Forage improvement practices are implemented only when profitable. Recent economic factors have not encouraged the implementation of forage improvement practices, especially on rangeland (Pope and Wagstaff 1987a, Wilson et al. 1987). If the economic situation warranted, additional forage could be produced on the available land in every region by applying various improvement practices (tables 11 and 12).

Stocker Cattle

In 1986, stocker cattle were located primarily in the NO (36% of the total), SO (28%), and NR (27%) regions (table 22). Since 1978, stocker cattle inventories have declined less than 7% in the 11 western states. In contrast, a decline of over 3.8 million head, or 24%, was seen in the SO region. Stocker cattle numbers inventoried during the summer would show a shift from these January 1 numbers as cattle are usually bought for stocker operations in the winter and early spring and

Table 22.—Inventory of stocker cattle (1,000 head) in 1978 and 1986 by Assessment region.

Region	1978 Stocker[1] numbers	1978 Percent of total	1986 Stocker[2] numbers	1986 Percent of total
California	1,207	3.0	1,695	4.4
Pacific Northwest	924	2.2	1,016	2.6
Northern Rocky	10,602	26.0	10,214	26.6
Southwest	822	2.1	647	1.7
Northern	12,771	31.3	13,887	36.2
Southern	14,448	35.4	10,933	28.5
Alaska	NA	NA	T[3]	T[3]
11 Western States	6,483	16.0	6,078	15.8
United States	40,774	100.0	38,395	100.0

[1] *Includes steers and "other" nonreplacement heifers weighing 500 pounds and over, plus steers, heifers, and bulls weighing under 500 pounds, minus cattle and calves on feed.*

[2] *Includes "other" nonreplacement heifers, steers, and calves, minus cattle on feed. Does not include 2,000 cattle on feed reported in "Other States" in source.*

[3] *Trace.*

Source: 1978 data: USDA Economic Research Service (1979). 1986 data: U.S. Department of Agriculture (1987), Agricultural Statistics.

moved to range and pasture for the growing season. However, the magnitude of these shifts would be small, and these January numbers show relative distribution of operations (table 22).

Stocker operations depend primarily on grazed forage as a feed source, but differ in the levels of management, capital inputs, and alternative feed sources. These production systems depend on starting weights of the calves, weights at marketing, length of feeding period, and kind of feed. One type of system purchases animals in late winter, pastures them for the summer, and sells them in the fall. The advantage of this system is the low cost of gain and the short feeding period which reduces price risk. This system involves less chance for large negative price margins than with other systems because the period the cattle are held by the operator is short, essentially just the growing season (Gee and Madsen 1988). Other systems purchase calves in the late fall and feed a ration of alfalfa hay or corn silage and small amounts of grain or other concentrates until grazed forage is available. These animals are held until spring or the following fall depending on cattle price fluctuations.

Two factors have encouraged increasing numbers of stocker operations to market cattle at heavier weights (Gee and Madsen 1988). Commercial feedlots have attempted to reduce feeding costs, increase the rate of turnover, and reduce price risks by beginning with heavier stocker cattle. Cow-calf producers have increasingly held calves after weaning to capture potential profits from additional growth and more benefits from herd improvement programs (Gee and Madsen 1988). In eight major cattle feeding states, the proportion of calves weighing less than 500 pounds in commercial feedlots in 1984 was only 52% of the proportion of lighter calves in the 1965 inventory (Gee and Madsen 1988). Heavier stocker cattle imply increased use of grazed forages and further trends in this direction would imply an increased demand for grazed forages nation-wide.

Sheep Industry Structure

Like the cattle industry, the sheep industry can be divided into breeding herds and fed animal (lamb) production. Lamb feeding operations vary from 1,000 to 50,000 animals (Council for Agricultural Science and Technology 1982). In 1980, nearly 43% of the lamb crop was sold to commercial feedlots or packing houses for fattening (Gee and Madsen 1983). This percentage varies across regions in relation to the availability of lush forage. In the Pacific Coast, weaned lambs can be sold for immediate slaughter. However, in drier parts in the Great Plains area and in the Southwest region, few lambs are considered fat enough for slaughter and these lambs are often fed in drylot facilities or grazed on crop residues such as beet tops or alfalfa stubble. Thus, unlike stocker cattle operations, fed lamb operations are often part of the breeding operation, and more often depend upon crop residue than range grazing to produce the animal to be sold to the feedlot. The breeding operations demand the greatest amount of grazed roughages in sheep production.

Of the 115,000 sheep enterprises in 1985, nearly 92,000 were located in the 17 western states and the 7 North Central states (American Sheep Producers Council Inc. 1987).[13] Characteristics of sheep operations vary with size and location. Nationally, 43% of producing ewes were in herds of 1,000 or more in 1978. Large herds (1,000 to 5,000 animals) were more common in the 17 western states (Gee and Madsen 1983). Farm flock

[13] *North Central states of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio.*

operations of less than 50 producing ewes are common in the midwestern and northeastern parts of the United States. A slight shift between 1969 and 1978 away from the medium-sized herds (100-199) to either herds of over 1,000 or less than 100 head may reflect the renewed interest in small farm flocks (Gee and Madsen 1983).

Important feed sources for sheep are public grazing and deeded nonirrigated pasture (table 18). In 1980, 1.8 million sheep grazed BLM-administered land and 1.3 million grazed on NFS lands, which represent 29% and 21%, respectively, of sheep in the western states. Since many operators use only one of these feed sources, these percentages may not represent the same sheep and 30% to 40% of all western sheep may rely on federal land (Gee and Madsen 1988). Operators may graze only part of their herd on public land, thus if all sheep within an enterprise are included, potentially more than 50% of sheep in the 17 western states are owned by enterprises affected by federal grazing land policies (Gee and Madsen 1988).

The large decrease in sheep inventories since the 1960s has significantly reduced the demand for grazed forage on traditional sheep ranges in the western United States. This grazing land has also been diverted to other uses, reducing the amount of federal land available for sheep grazing (Gee and Madsen 1983). Stable inventories since 1980 suggest that demand for forage will continue at the current levels.

Seasonal Dependency on Forage

The total feed mix for a livestock operation is a combination of many feed sources available at different times of the year. Sources, such as hay, are used to supplement unavailable or short supplies of feed. Seasonal availability of forage is a function of climate, management, land ownership patterns, and land use patterns. Management activities can mitigate the seasonal supply of forage by diversifying the type of plant species grown, such as extending warm-season pastures with the seeding of cool-season species in the South, or seeding warm-season species into the predominantly cool-season pastures in the North. In the western United States, livestock grazed public lands before these lands were managed as federal ownerships. These patterns of intermixing private with public grazing established a precedent for the historical dependency of grazing upon federal lands for at least part of the yearly forage needs (Bedell 1984).

When dependency is defined as AUMs of feed provided by public lands divided by total annual AUMs required by the entire livestock herd, the dependency level for cattle operations ranges from 11% to 60% across the 17 western states (USDA Forest Service and USDI Bureau of Land Management 1986). For sheep operations, the dependency levels range from 24% to 49%. In states such as New Mexico, livestock may graze federal land for the entire year, whereas in other states such as Montana, a seasonal use is more common.

The absolute magnitudes of these dependencies may not adequately reflect the potential changes in livestock operations if these seasonal sources of forage are changed. The actual impact will be a function of how the seasonally available sources interact with other sources of feed. For example, April, May, and June are critical feed months in eastern Oregon, and ranches with access to BLM grazing during this time can carry a larger herd in other months of the year (Bedell 1984).

Although ownership patterns contribute to seasonal dependencies, land use patterns also foster seasonal availabilities in forage sources. In southern Kansas, Oklahoma, and the Texas panhandle, wheat is planted in the fall, and with favorable moisture, the crop provides ideal winter pasture for several hundred thousand calves (Gee and Madsen 1988). Fields can be grazed under proper management from October or November to March, without harm to the wheat crop. The use of this stocker system varies with the annual changes in moisture, and, under dry conditions, very few cattle will be grazed on the wheat pastures (Herbel and Baltensperger 1985).

TECHNOLOGICAL ENHANCEMENTS IN LIVESTOCK PRODUCTION

Technological Developments and their Influence on Livestock Production

The development and implementation of technology and its influence on animal production changed the use of forest and range vegetation (table 23). The introduction of cattle, horses, and sheep to North America changed the mix of grazers in forest and rangeland ecosystems. The development of refrigeration (1801), livestock shipment by rail (1852), and refrigerated railroad cars (1868) extended the distance from markets that livestock could be produced. As a result, vast areas of grazingland were opened in the interior of the United States. The development of the windmill (1854) improved the distribution of livestock across the landscape. Mechanical developments such as the hay baler and the grain elevator (1842) allowed forage harvested in years of good precipitation to be stored and used in drought (Smith 1979, Taylor 1984). The development of irrigation (1847) in the semi-arid west, and the introduction of improved forage species (1884 and 1888) diversified and nutritionally improved the feed mix and began to shift the use of land from grazing to cropping.

Technology has increased the type and quantity of outputs from the grazing animal. The introduction of exotic breeds (1817) and the development of growth stimulants (1949) have helped to increase meat or milk production per animal. Alternative livestock products such as angora (1849) diversified the grazing industry. The widespread implementation of artificial insemination (1939) and the development of drugs for estrous synchronization (1979) increased an operator's ability to genetically improve livestock production.

Table 23.—History of developments affecting rangeland management in the United States.

Year	Development
1636	First meat packing plant
1783	Improved cattle introduced to United States
1801	Refrigerator invented
1817	First Hereford and Jersey imported to United States
1834	Mechanical refrigeration developed
1836	First recorded auction sale of livestock in Ohio
1837	John Deere plows with steel share and smooth wrought iron moldboard
1842	First grain elevator in Buffalo, New York
	First rail shipment of milk
1843	Commercial fertilizer industry began
1847	Irrigation agriculture initiated in Utah
1849	Angora goats introduced to United States
1852	First livestock shipment by rail
1854	Windmill invented, Connecticut
1863	Dryland farming in Utah
1865	Chicago's Union Stockyards opened
1866	Goodnight and Loving trail cattle from Texas to Colorado and New Mexico
1867	First patent for barbed wire fencing, New York
1868	Refrigerated railroad car patented
1869	Transcontinental railroad completed
	Fresh meat successfully shipped from Chicago to Boston in refrigerated railroad cars; cooled by ice and salt
1874	Glidden barbed wire patent granted
1875	First continuous shipments of beef to England
1884	Smooth brome grass introduced
1886-87	Disaster in Great Plains cattle industry; winter storm, drought, overgrazing; this extends plowed agriculture into semi-arid and arid sections of United States
1888	Crested wheatgrass introduced from Russia
1888	Meat first shipped in railroad cars with mechanical refrigeration
1895	Commercial feed industry began in Chicago
1915	Refrigerated warehouse construction in meat packing plants
1927	Federal grading of beef initiated
1930	Range Livestock Research Station established at Miles City, Montana
1939	Artificial insemination widely used
1941	First performance bull testing station (Texas)
1942	Growth regulation property of 2,4-D discovered
1949	Usefullness of antibiotics in animal nutrition demonstrated
1950	Commercial feeding of stilbestrol to beef cattle began
1952	First successful breeding using frozen semen
1960	Cubing and wafering machines revolutionized hay handling
1960	Boxed beef processing began to influence industry
1978	First calf from a frozen embryo in the United States
1979	Diethylstilbestrol banned from use in cattle feeding
1979	First prostaglandin (Lutalyse) approved for use in estrous synchronization
1981	First test tube calf born in the United States
1982	First identical twin calves born in the United States as a result of microsurgery

Source: Smith (1979), Taylor (1984).

Increased feeding efficiency in animals has led to the doubling of market weights (Fontenot 1984). Live weight marketed per breeding female in beef cattle has gone from 220 pounds in 1925 to 317 in 1950 to 482 in 1975. Live weight marketed per breeding female of sheep has risen from 59 pounds in 1925 to 90 in 1950 to 130 in 1975. Milk marketed per breeding female in dairy cattle has risen from 4,392 pounds in 1925 to 10,513 in 1975. One half the cow numbers are producing the same quantity of milk produced 30 years ago using one-third less feed (National Research Council, Board on Agriculture, Committee on a National Strategy for Biotechnology in Agriculture 1987).

Although many technologies have been developed to improve livestock production and the efficiency with which livestock harvest forage, the implementation of these technologies is lacking on rangelands (Lewis and Engle 1982). On the Great Plains, conventional barbed and woven wire are the most commonly used fencing technologies and solar-powered electric energizers are one of the least commonly implemented fencing technologies (table 24). Technologies to benefit both livestock and wildlife have had limited application. Antelope pass fencing is fully developed but has had little or no application (table 24).

Fed Beef Production

Fed beef are cattle that have been fed a fattening ration for the slaughter market. Stocker calves weighing from 500 to 750 pounds are purchased, fed a fattening ration for 4 months to 1 year, and sold at weights between 900 to 1,200 pounds (Nelson 1984). Little forage is used in this segment of the beef production, however this segment produces the final product and, thus, influences the supply and demand of meat.

At one time, all grain-fed beef cattle were produced on farms, and the major center of fed beef production was the Corn Belt states (Gee and Madsen 1988, Van Arsdall and Nelson 1983). In 1950, less than 40% of the cattle on feed were in the 17 western states. The development of irrigation, hybrid sorghum grains, and increased grain production in the Great Plains and West initiated shifts in the regional distribution of cattle feeding operations. Preceding and coincident with these agricultural developments were a number of discoveries related to beef nutrition and pest and disease control. These discoveries allowed for increased concentrations of cattle (Reimund et al. 1981). Commercial feedlots with a capacity of 16,000 head or more accounted for only 16% of the marketings in 1967, but by 1984, feedlots of this size had cornered 51% of all fed beef marketings (Gee and Madsen 1988). Whereas farmer-feedlots were vertically integrated with feed grain production and cattle feeding occuring during seasons when labor was not needed for crop production, these large commercial feedlots could separate grain production from livestock feeding, operate year-round, and reduce the seasonality of fed-beef production (Reimund et al. 1981). These technological advances coupled with the strong consumer demand for beef fueled the rapid expansion of cattle feeding during the 1960s and 1970s (Van Arsdall and Nelson 1983). In 1960, the proportion of the calf crop slaughtered as nonfed was 21%. By the early 1970s, this proportion dropped to 5% (Reimund et al. 1981). In

Table 24.—Status of development and application of facilities and equipment used to manage animals for managing and improving range ecosystems of the Great Plains.

Facility or equipment item[1]	Status of development[2]	Extent of application[3]
A. Fencing		
1. Conventional barbed or woven wire	3	3
2. Big game fencing	3	2
3 Suspension fencing	3	1
4. Electric, conventional	3	3
5. Electric, high efficiency	3	1
6. Solar-powered electric energizer	3	1
7. Mechanized fence builder	3	1
8. Antelope pass fencing	3	1
B. Water developments		
1. Improvement of natural supply	3	3
2. Wells, wind or power pumped	3	3
3. Deep wells	3	1
4. Reservoirs and dugouts	3	3
5. Rain catchments	3	1
6. Storage facilities	3	1
7. Piping	3	1
8. Heaters, propane	3	2
9. Heaters, solar-powered	2	1
C. Handling and animal management		
1. Corrals, related facilities	3	3
2. Portable corrals	3	1
3. Identification		
Fire branding equipment	3	3
Freeze branding equipment	3	2
Ear tags and bands	3	2
Electronic	1	1
Telemetered	3	2
4. Weighing		
Conventional scale	3	2
Electronic, automatic recording	1	1
5. Windbreaks, shelter, shades	3	2

[1]*Equipment and facilities are grouped according to their principal use. It is recognized that many have a variety of applications.*

[2]*Status of development:*

1 = Undeveloped.

2 = Various stages of development, not available for general use.

3 = Fully developed and available for use; refinements may be made in existing equipment.

[3]*Extent of optimum application:*

1 = None or very limited.

2 = Significant, but incomplete.

3 = Complete or near complete.

Source: Lewis and Engle (1982).

1984, 76% of the cattle on feed were in the 17 western states (Gee and Madsen 1988).

Although fed beef production occurs in most states, the largest production is located in 13 states: Texas, Nebraska, Kansas, Colorado, South Dakota, Minnesota, Iowa, Illinois, Indiana, Ohio, Michigan, Arizona, and California. In the last 5 years, marketings declined in two of the leading cattle feeding states (Iowa and California). The trend toward more specialization, low returns from cattle feeding, and a greater emphasis on crop production in Iowa contributed to this reduction because feedlots are generally small and part of a diversified farming operation (Gee and Madsen 1988). In California, most feedlots are large commercial operations and their decline reflects declines in slaughter plant facilities, the high costs of production associated partly with transportation of both cattle and feed into the state, and a reduction in the fed beef price premium enjoyed in past years (Gee and Madsen 1988). Fed beef marketings have been expanding fairly consistently in Colorado, Kansas, Nebraska, Texas, and Washington. The construction of new slaughter plant facilities, a surplus of feed grains, and plenty of easily accessible stocker cattle facilitates this expansion (Gee and Madsen 1988). In future years, cattle feeding will be concentrated more in the Central Plains with declines in the extreme Southwest and Cornbelt (Drabenstott and Duncan 1982, Gee and Madsen 1988).

Although the total costs are lower for large commercial feedlots, these operations are more sensitive to price

variations on inputs because nearly 99% of their total costs are variable costs. Commercial feedlots generally buy all their feed, whereas farmer feedlots are diversified operations in which all or a great proportion of the feed is produced on the farm (Van Arsdall and Nelson 1983). Variable costs were only 84% of the farmer feedlot total costs in 1979 (Drabenstott and Duncan 1982). Thus, shifts in the price of grain through rising exports, or changing government agricultural policies, affect fed beef production.

Future Technologies for Livestock Production

The future productivity of livestock could be increased by the development and implementation of 150 current and potential technologies (U.S. Congress, Office of Technology Assessment 1986b). These technologies span the entire spectrum of animal production from modifying and controlling the animal's environment to pest and disease control to manipulating and changing the animal's physiology (table 25). Many technologies currently exist to control pest and disease and to improve livestock reproduction rates. Genetic research has focused on altering livestock to improve reproductive performance, weight gain, disease resistance, or livestock coat characteristics (U.S. Congress, Office of Technology Assessment 1988). Enhancing the rate and efficiency of muscle growth to produce a leaner animal may be possible in the near future through the administration of recombinant hormones. Technologies currently exist that can optimize tissue growth through the synchronization of nutrition with the animal's need for protein growth. Technologies are needed that allow more precise regulation of growth in animals and integrated growth management programs that will coordinate the application of these technologies in a holistic approach (National Research Council, Committee on Technological Options to Improve the Nutritional Attributes of Animal Products 1988).

The impact of these emerging technologies on animal production efficiency is expected to increase the pounds of meat per pound of feed from the actual 1982 value of 0.07 to 0.072 by 2000, and increase the number of calves per cow from the actual 1982 value of 0.88 to 1.0 in 2000 (U.S. Congress, Office of Technology Assessment 1986b). This indicates an annual increase of 0.2% in feed conversion efficiency and 0.7% in calving success.

The impact of these technologies on the forage demand from forest and rangelands is difficult to determine. Increases in feed efficiency will produce more meat per pound of feed, a distinct advantage in feedlots. Kalter and Tauer (1987) reported that the greatest near-term economic potential involves the use of bio-tech-created natural hormones in animal protein synthesis. Adoption of these technologies will result in improvements in feed efficiency, increased milk production, reductions in the total nutrient requirements for animals, and lower crop, land, and consumer prices. Land for grain and roughage production could decline 3.4 to 10 million acres (Kalter and Tauer 1987).

Table 25.—Emerging technologies for animal production and likely year of introduction under three future environments of technological development.

	Technology environments		
	More new technology[1]	Most likely[2]	Less new technology[3]
Genetic engineering:			
Production of pharmaceuticals	1982	1982	1982
Control of infectious diseases	1983	1983	1983
Improvements in animal production	1990	2000	>2000
Genetic abnormalities			
Detection	1990	1995	>2000
Treatment	1990	2000	>2000
Control of cancer and leukemia	1990	1990	>2000
Animal production:			
Cycle regulation	1985	1989	1995
Superovulation, embryo transfer, and embryo manipulations	1983	1983	1983
Improvement of fertility	1990	1995	1995
Genetic engineering techniques for farm animals	1995	2000	>2000
Regulation of growth and development:			
Muscle and adipose tissue accretion	1987	1992	>2000
Hormone, serum, and tissue factors important to growth	1995	2000	>2000
Immunological attraction of animals	1990	1995	>2000
Measuring body composition and animal identification	1990	1995	>2000

Table 25.—Continued

	Technology environments		
	More new technology[1]	Most likely[2]	Less new technology[3]
Animal nutrition:			
Animal production consumption and human health	1995	2000	>2000
Alimentary tract microbiology and digestive physiology	1989	2000	>2000
Voluntary feed intake and efficiency of animal production	1989	1995	>2000
Maternal nutrition and progency development	1984	1984	1984
Livestock pest control:			
Slow release insecticides	1984	1984	1984
Vaccines	1986	1986	1991
Integrated systems	1987	1989	1994
Modification of insect habitat	2000	2000	2000
Insect-resistant animals	2000	2000	2000
Utilizing immunity systems	1990	1990	1995
Disease control:			
Data management and systems analysis	1980	1980	1980
Diagnostic methodologies	1986	1986	1988
Selection for disease resistance	1994	1999	>2000
Genetic engineering			
Embryos	1995	1999	>2000
Micro-organism	1988	1989	1999
Immunobiology	1983	1983	1983
Environment and animal behavior:			
Energy conservation:			
Non-integrated system	1985	1990	2000
Integrated system	1995	2000	>2000
Optimizing total stress	1995	2000	>2000
Stress and immunity	1995	2000	>2000
Photoregulation of physiological phenomena	1990	1990	>2000
Utilization of crop residues and animal wastes:			
Energy from manure	1985	1985	1985
Energy from crop residues	1990	1990	>2000
Animal feed from crop residue	1990	1990	>2000
Animal feed from manure	1990	1995	>2000
Monitoring and control technologies:			
Sensors, controllers, displayers	1985	1985	1985
Communication and Information management:			
Networks, software, and database systems	1985	1985	1985
Manufacturing management systems	1987	1990	2000
Expert systems	1992	1995	2000
Telecommunications:			
Digital communication	1990	2000	>2000
Fiber optics	1990	2000	>2000
Videotex and teletext	1985	1985	1985
Value-added networks	1985	1985	1985
Integrated services digital network	1987	1990	2000
Remote sensing	1985	1985	1985

[1]*Assumes to year 2000: (1) a real growth rate in research and extension expenditures of 4%, and (2) all other factors more favorable than those of the most likely environment.*

[2]*Assumes to year 2000: (1) a real growth rate in research and extension expenditures of 2%, and (2) the continuation of all other forces that have shaped past development and adoption of technology.*

[3]*Assumes to year 2000: (1) no real growth rate in research and extension expenditures, and (2) all other factors less favorable than those of the most likely environment.*

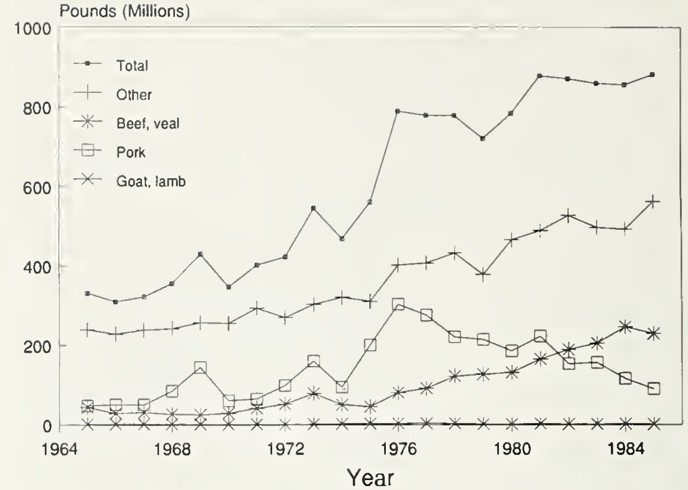
Source: After U.S. Congress Office of Technology Assessment (1986b).

DEMAND FOR MEAT

World Production and International Trade

The world meat output that enters international trade is only 7% of total world meat production. Bovine meat, which includes beef, had the largest share of the international meat trade; poultry has been the fastest growing segment (Food and Agriculture Organization 1983). The United States share of the international meat trade (bovine, sheep, poultry, and pork) was only 4.6% in 1980. By type of product, U.S. meat exports have increased (fig. 41), but these exports were less than 1.5% of total U.S. meat supplies in 1985 (U.S. Department of Agriculture [various years]). Lamb and mutton exports were 1% of sheep supplies in 1985. Pork exports were 1.6% of total pork supplies, a drop from the peak of 3.1% in 1976 (fig. 41). Beef exports have increased since 1970, but these exports were only 1.5% of the total beef supplies in the United States in 1985 (table 26).

World-wide agricultural exports during the 1970s reflected a combination of favorable factors: increased meat imports by the Soviet Union as it profited from higher oil and raw material prices, rapid income growth in developing countries used to improve diets, rapid export growth in developing countries, increased ability to borrow against oil supplies, and currency exchange rates, particularly the exchange rate of the U.S. dollar (Sanderson 1984). Countries such as the United States increased their share of the world meat exports by improved beef production technologies. The economic recession of the 1970s and higher meat prices in the early 1980s led to increased self-sufficiency rates for meat production (Food and Agriculture Organization 1983). Beef and veal production increased from 1961 to 1984 in Eastern Europe, USSR, North America, and Africa and Asia (fig. 42).



NOTE.--Other includes sausage, bologna, variety meats, canned meat, and meat products.

Source: USDA (1965-1986)

Figure 41.—United States meat exports by type of product.

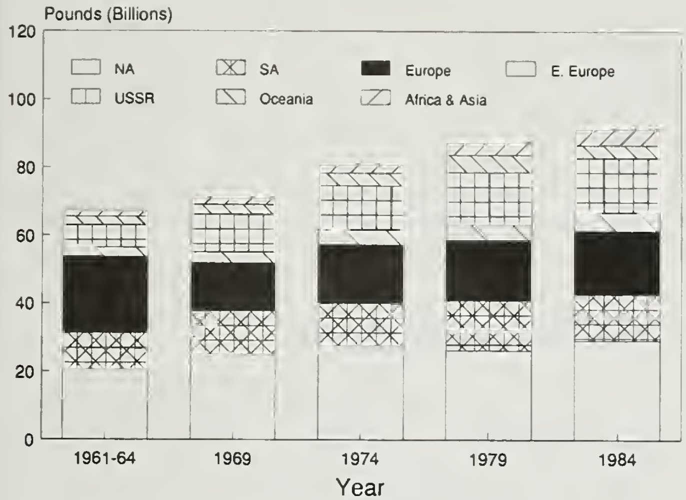
Depressed prices in the world meat trade were the result of a slack demand, continued rapid technological improvements in animal production, and protectionist policies (Food and Agriculture Organization 1983). Protectionist policies for the livestock sector have

Table 26.—Beef supply and foreign trade for United States, 1970-85.

Year	Supply (million pounds): Total	Supply (million pounds): Imports	Supply (million pounds): Exports and shipments	Percentage of total supply: Imports	Percentage of total supply: Exports and shipments
1970	23,830	1,792	101	7.5	0.4
1971	23,976	1,734	117	7.2	0.5
1972	24,739	1,960	114	7.9	0.5
1973	23,635	1,990	144	8.4	0.6
1974	25,200	1,615	115	6,4	0.5
1975	26,135	1,758	110	6.7	0.4
1976	28,392	2,073	158	7.3	0.6
1977	27,682	1,939	167	7.0	0.6
1978	26,854	2,297	214	8.6	0.8
1979	24,257	2,405	215	9.9	0.9
1980	24,057	2,064	220	8.6	0.9
1981	24,460	1,743	252	7.1	1.0
1982	24,732	1,939	305	7.8	1.2
1983	25,468	1,931	312	7.6	1.2
1984	25,746	1,823	376	7.1	1.5
1985	26,154	2,068	379	7.9	1.5

Note: Includes products converted to carcass weight equivalent. Edible offals are not part of the carcass and therefore not included.

Source: Gee and Madsen (1988). Data from USDA Economic Research Service, Livestock and Meat Statistics 1983, Statistical Bulletin 715, and Food Consumption, Prices and Expenditures. 1985. Statistical Bulletin 749.



NOTE.--Oceania = Australia, New Zealand, South Pacific Islands. NA, SA = North and South America.

Source: USDA (1961-1984)

Figure 42.—Annual beef and veal production by world regions, 1961-1984.

become more widespread, with approximately 25% of the total world meat exports heavily subsidized.

International beef and veal production will not soon see the expansive growth of the 1970s (Food and Agriculture Organization 1983). Rising demand from population growth or increased income levels in developing countries will stimulate meat production through intensive poultry and pig production, or rural and pasture-based ruminant production (beef, sheep, goats) in countries such as Asia, Africa and Latin America. Pig meat recently has replaced bovine meat as the principal meat worldwide, however the fast growth in poultry production may change that picture in the future (Food and Agriculture Organization 1983).

Projections by the Food and Agriculture Organization suggested that the world consumption of meat will grow only 1% a year in the 1980s, with the demand in bovine meat (beef) growing only 0.7% annually. Extending projections to 2000, Resources for the Future indicated an annual rate of increase in total demand (domestic plus net trade) for all meats to be 2.4% globally over the 1980-2000 period, a drop from the 3.1% increase during 1969-80 (Sanderson 1984). The implication to international meat trade is a slow growth overall or decline in growth for some meat products (Food and Agriculture Organization 1983). Many developing countries are moving toward self-sufficiency in poultry and pig production. Trade in meat from ruminant animals may increase in the Near East and North Africa, but favoring neighboring suppliers in Asia and East Africa (Food and Agriculture Organization 1983). The implication to the United States meat industries is that there is little likelihood of the international trade improving over the next 20 years (Sanderson 1984). Thus, demand for meat in the United States will be primarily a function of domestic demands.

Consumer Demand for Meat in the United States

Meat Consumption

Total per capita meat consumption increased slightly from 1965 to 1985 (fig. 43). Beef surpassed pork consumption in 1953 (Nalivka et al. 1986) and steadily increased to a peak of 89 pounds per capita (edible weight[14]) in 1976 (fig. 43). Thereafter, beef consumption declined to a low of 76.5 pounds in 1980 and has since remained below 80 pounds. Lamb and mutton consumption was greater than 3 pounds per capita before 1960 (Stucker and Parham 1984). Consumption declined from 2.6 pounds (edible weight) in 1970 to 1.1 pounds by 1986, a very small amount compared with a total beef, veal, pork, lamb and mutton per capita consumption of 120.5 pounds.

The largest increases in per capita consumption were associated with poultry and fish (fig. 43). Consumption of chicken rose from 23 pounds in 1965 to 39.7 pounds (edible weight) in 1985. Turkey consumption nearly doubled in the same time period (USDA Economic Research Service 1986). The advances in harvesting technology increased the accessibility of fresh fish, and consumption rose from 10.8 pounds in 1965 to 14.5 pounds in 1985. Indications are that fish consumption will continue to increase (Blaylock and Smallwood 1986).

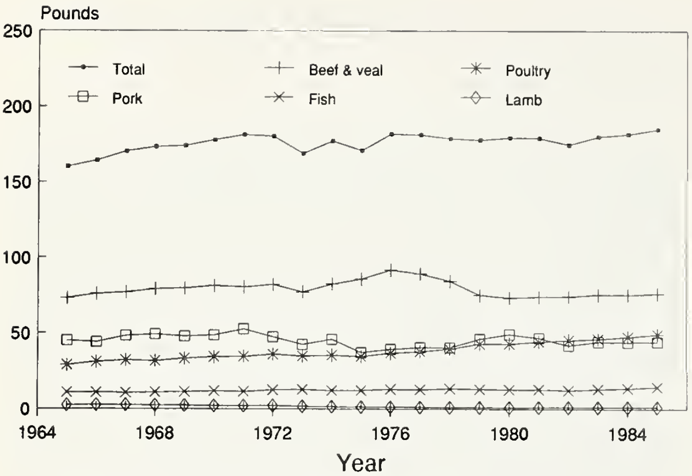
Studies on the composition of food supply in the United States have indicated a rise in the consumption of low-fat animal products, such as low-fat milk and fish, but an increase in the use of high-fat food such as hard processed cheese and baking and frying fats of both vegetable and animal origin. Dietary survey data and supermarket sales suggested that the fastest growing food items were meat mixtures, where meat, poultry, or fish are mixed with grains or pasta (National Research Council, Committee on Technological Options to Improve the Nutritional Attributes of Animal Products 1988).

Population Size and Age Distribution

Population growth alone increases the total consumption of meat. The population growth rate in the United States peaked in 1950-55 at 2.1% annually. Growth during the 1970s was 1.1% annually. Future increases in population growth are estimated to decline from annual rates of 1.0% to 0.2% by 2040 (Darr in press).

Changes in the age class distribution with the overall increase in the median age will affect the per capita consumption of meat. The age class distribution is shifting to middle and older groups, and older persons are not inclined to consume as much meat as younger individuals (Blaylock and Smallwood 1986). Food spending patterns differ across age classes also. Younger individuals are forming eating patterns relying on fast

[14]*Edible weight is used in comparing meat consumption across type of eat. Edible weight (beef) = 0.698 times (carcass weight) (USDA Economic Research Service 1986).*



Source: USDA, Economic Research Service (1986)

Figure 43.—Per capita meat consumption in the United States by edible weight.

food, more purchases away from home, and preferences for the lower priced cuts or even less meat consumption (Blaylock and Myers 1987, Gee and Madsen 1988). Regional differences in meat purchases tend to be small (Blaylock and Myers 1987).

Disposable Personal Income

Food competes for the consumer's dollar against nonfood items such as housing, clothes, cars, and recreation. Thus, the total budget allocation process must be analyzed in explaining meat consumption behavior (Haidacher et al. 1982). Studies in consumer spending patterns indicate that disposable income has significantly affected consumer spending patterns worldwide. Where disposable income is low, cereals make up a major portion of the diet. With increasing income, a wider variety of foods, including more meat, are eaten (Blaylock and Smallwood 1986, Food and Agriculture Organization 1983). Per capita disposable income in the United States has been higher than other parts of the world, and the high percentage of meat and poultry in the average American diet (over 33%) reflects this economic situation.

In the United States, consumption patterns are being established under a situation of rising nonfood costs and an availability of cheap food. As food costs as a whole increase, consumers tend to consume lower cost food products. Because beef is a major component of the food purchased and is relatively expensive, the amount of beef purchased tends to be reduced before that of many other foods when income is reduced (Gee and Madsen 1988). Before 1980, rising per capita disposable income levels were associated with rising per capita meat consumption. After 1980, per capita disposable income has continued to rise but the percentage spent on beef has declined. Per capita disposable income (1982 constant dollars) has increased from $9,829 in 1980 to $10,947 in 1986, whereas the percent spent on beef has fallen continuously from 2.4% in 1979 to 1.5% in 1986.

When individual income groups are analyzed, increases in meat consumption are still occurring within lower income groups, but the increases are not great in higher income groups. Thus, changes in the distribution of incomes will change the consumption of meat more than an increase in the average per capita income across the nation (Buse 1986).

Prices and Marketing Strategies

The cause for recent shifts and declines in per capita meat consumption is uncertain. Changes in sociological factors such as a more health conscious public or taste preferences, or changes in economic factors such as increased disposable income have been suggested as reasons for the shifts in consumer demand (Breidenstein 1988, Doane's Agricultural Report 1987, Drabenstott and Duncan 1982, Greenhouse 1986, Walter 1985). The hypotheses require numerous observations before these factors can be quantified econometrically (Crom 1984) and many studies have been and are being conducted to determine if structural changes have occurred in the demand for meat (Braschler 1983, Chavas 1983, Conway et al. 1987, Dahlgran 1987, Haidacher et al. 1982, Kokoski 1986, Moschini and Meilke 1984, Wohlgenant 1985).

Record high levels of meat production have placed a large and diverse amount of meat in the supermarket case. Beef demand is impacted by the availability of substitute products at lower prices than beef (Greenhouse 1986). Cost efficiencies resulting from the integration of production and processing activities have given a competitive advantage to poultry production that beef and lamb producers have not enjoyed. Not only is the conversion of feed more efficient in poultry than in cattle, but improved production technologies such as disease control, feeding practices, and confinement housing have allowed poultry production to maintain lower prices than beef (fig. 44). In the absence of such technologies, the retail price for chicken would have been 175% higher than the actual price in 1983 (Lipton 1986). In 1960, beef prices were twice chicken prices and by 1986 had risen to over three times chicken prices (fig. 44).

The continued ability of retailers to maintain profit from beef reflects their great buying power (many different packers) and the diversity of meat products available. When beef prices rise, retailers can offer the lower-priced meat products, such as poultry, to satisfy consumer demand (Gee and Madsen 1988). Packers and processors have developed brand lines of meat to reduce the ease with which a retailer can switch to alternative suppliers and have increased promotion efforts toward consumers to reduce the attractiveness of substituting other meats for beef. Although the results of these efforts will not be known for some time (Cohn et al. 1987), it is clear that meat production and marketing is highly competitive.

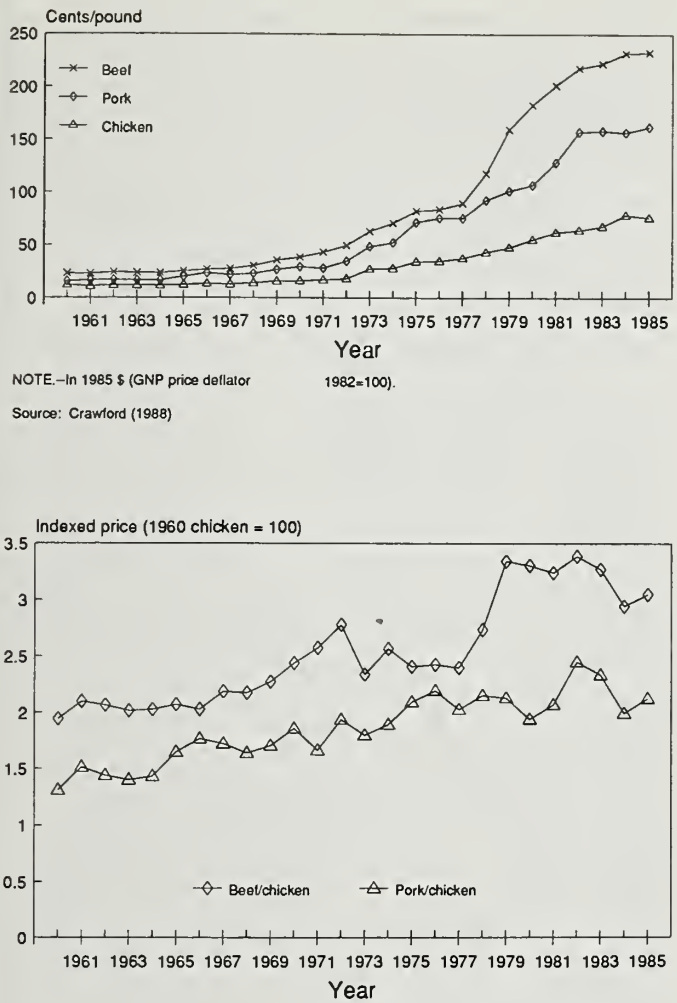


Figure 44.—Retail and indexed prices for whole chickens, pork, and choice beef, 1960-1985.

New product development in the meat industry has been spurred by the changes taking place in society. Working couples and single heads of households are attracted to convenience foods with short preparation time. In addition, increased amounts of food are being consumed away from home. In 1962, 28% of total food expenditures were spent eating away from home, and by 1985, the percentage had risen to 43%; fast food outlets cornered an increasing share of food expenditures (Lipton 1986). Concern about nutrition and health have raised additional issues about diet. Demographic changes in the population also are spurring new product development.

New poultry products developed to meet the changing wants and needs of consumers have helped to maintain the high demand for poultry. In the 1950s, shoppers would likely have purchased a store-labeled whole chicken. In the 1980s, consumers can select from various brand-name chickens, whole or cut-up chicken, boneless chicken or chunks, or pre-cooked items, such as barbecue turkey (Lipton 1986). Higher production costs have limited the new product development in the pork industry, although many new pork products have been developed (Gee and Madsen 1988). The relatively high consumer demand that beef has enjoyed for nearly 30 years has not exerted much pressure for new product development.

Boxed beef represents the last major innovation in the beef industry (Gee and Madsen 1988). Before this development 20 years ago, beef left the packer as sections of the animal, forequarters and hindquarters. Now beef is cut up into smaller portions called primal or subprimal cuts, sealed in vacuum-pack bags, and shipped out in cardboard boxes, hence the name boxed beef. In 1979, total packer boxed beef was 50% of fed cattle marketings, but by 1984, had increased to 77% (Gee and Madsen 1988). With the development of boxed beef, the slaughtering and packing of animals became assembly-line tasks and the average number of carcasses handled increased from 125 to 400 a day (Greenhouse 1986). But this innovation, a major step in increased efficiency of beef production, did not alter the end product provided to consumers.

Recently developed beef products have included prepackaged meat portions, precooked products, boneless cuts, and shredded beef with sauces (Gee and Madsen 1988, Greenhouse 1986). Perhaps the most encouraging recent development is the ability to restructure beef into fabricated steaks from high quality trimmings, much like the fabricated crabmeat now available (Gee and Madsen 1988). The beef fabrication process, developed at Colorado State University (Best 1986), would allow for uniform construction and fat content of each cut. The resultant product appears like a steak cut from the side of an animal. The Food and Drug Administration and the U.S. Department of Agriculture must approve the process before it can be used on a commercial basis.

Another production and marketing strategy being developed within the beef industry is the use of brand names, similar to brand development in chicken. This development is occurring for larger packing companies, for smaller livestock operations, and in Europe as well as in the United States (Geoghegan 1987, Greenhouse 1986, Howard 1987). Characteristics promoted include low fat, low cholesterol, production free from unsafe residues or chemicals, and taste (Greenhouse 1986, Howard 1987, Jackson 1985). In addition, the benefits of wild game meat are also being promoted as low in fat and cholesterol (Sheram 1986).

Projecting Meat Demand and Implications for Forage Demand

Short term projections indicate that demand for meat will be steady or will slowly rise (Walter 1985). Sanderson (1984), reporting on projections compiled by Resources for the Future, indicated a 0.9% growth in the total demand for meat (primarily domestic demand) in the United States, similar to the projected future population growth (Darr in press). This total demand for meat is less than the 1.4% annual increase witnessed during the 1970s. A work group consensus, at the Future

Agricultural Technology and Resource Conservation symposium (Smith 1984), was that beef per capita consumption would increase only slightly from 1984 to 2030 (table 27). This slow increase in per capita consumption suggests that increased demand for meat production will be primarily a function of population growth. The meat and beef industries have been characterized as "mature" industries, and growth in demand for mature industries is dependent entirely upon population growth (Fedkiw 1987).

In assessing the likely future trends in food consumption, Blaylock and Smallwood (1986) suggested that food groups likely to increase most were food away from home, fish, fresh fruits, and alcoholic beverages. Less than 40% of the total beef purchases are made away from home (Baker and Duewer 1983, Buse 1986). Beef is a small percentage of food purchased at restaurants and a much larger percent of food purchased for home (Thurman 1986). Thus, increases in beef seen as a result of increases in food purchases away from home will be smaller.

The cause for recent shifts and declines in per capita meat consumption is uncertain. Changes in sociological factors such as a more health conscious public, or economic factors such as record high levels of meat production will require a few years of data before shifts in consumer demand are quantified. For this assessment, population and income projections will be used to determine the future demand for meat production.

Forage demand could be greater if the lean beef production required only forage to finish animals. The recent trends are for a shorter period in the feedlot and not necessarily a longer period on grass. This would imply less grain demand rather than an increased forage demand. If per capita beef consumption increased and the increase was toward lean meat, then the forage demand would be greater to meet increased production of beef and lamb meat.

FORAGE AS AN INPUT TO ENERGY PRODUCTION

Projections made in the present assessment are based on the assumption that historical trends will continue to shape the future supply/demand and that changes in resource demand and land use will be an outgrowth of these trends and not abrupt discontinuities from the past. The possibility exists for a significant departure from historical trends. Two events that may dramatically alter the future management and use of forage resources are climatic change (Chapter 2) and the development of an energy industry using forage biomass as a feedstock.

Technological barriers and a significant drop in oil prices decreased the interest in biofuels generated during the 1970s oil crisis. Renewed interest will depend on (1) the cost and availability of oil, (2) the potential for replacing oil with coal, (3) developments in biomass conversion technologies, and (4) the availability of biomass (Byington 1988). Uncertainty exists within each of these areas. Adequate oil supplies are expected for another 30 years, although political factors and the desire to remain energy independent could raise oil prices through import duties and taxes (Byington 1988). Coal's high energy content per volume, concentration in major deposits, and vast reserves are balanced by high conversion costs and environmental considerations.

The advantages of biomass as an energy source are that biomass is a renewable resource, and converts with relatively few adverse environmental impacts when perennial vegetation is used. Limitations on biomass utilization are that it is a highly dispersed resource, is bulky, and has a relatively high water content. Although the conversion of biomass to ethanol has the advantage in that the end product is a usable energy product, the current economic feasibility of forage as a biofuel is still lacking (Byington 1988).

Byington (1988) presented a scenario regarding the future of biofuels and forage resources. Spurred by issues

Table 27.—Per capita consumption (pounds per person) in 1984, and estimated for 2000, and 2030.

Item	1984		2000		2030	
	Retail wt.	Carcass wt.	Retail wt.	Carcass wt.	Retail wt.	Carcass wt.
Beef	77	104	80	108	80	108
Veal	2	2	2	2	2	2
Pork	60	65	60	65	60	65
Lamb	2	3	2	3	2	3
Dairy products	540		520		510	
Chicken						
broilers	49		55		55	
mature chickens	3		3		3	
Turkey	11		13		15	
Eggs	36		33		30	
Fish	13		18		27	

Source: Smith (1984).

such as balance of payments, national security, idle cropland, and environmental concerns about climate change, the development of a forage biofuel industry is given government incentives such as: (1) laws mandating biofuel use, particularly in urban areas for environmental reasons, (2) government vehicle fleet use of biofuels, (3) tax breaks, (4) low-cost financing, (5) technical assistance, (6) price supports, and (7) increasing fossil fuel prices through taxes. Oil reserves are depleted in 30 years, and liquid fuels from coal become the least expensive fuel source. Biofuel development continues and eventually environmental concerns about coal and possible economic advantages over coal shift energy use to biofuels.

Under this scenario, a biofuels industry based on forage could create a new demand for land producing herbaceous material. The short-term impact on forage-producing lands will be marginal as cropland is used to supply this new demand. The long-term impact could be significant as cropland shifts back into crop production and an expanding beef herd and biofuel industry cause an intensification of management on pasture lands. Higher returns would shift land use from forage to biofuel production; livestock grazing would be eliminated on productive pasture and grazing lands where haying is possible. Substantial pasture and rangeland area in the South could be taken out of livestock production. Specific needs in regional livestock industries, such as supplemental feed in the northern regions, or land use patterns where only small blocks of hayland are available, would restrict the conversion of all grazinglands to biofuel production (Byington 1988). Grazing would remain on forested land in the South, range and pasture lands in the West, and land with no cropland conversion potential. Byington (1988) concluded that adequate forage supplies for livestock in 2040 would become unlikely if an expanded demand for cropland or forages developed.

SUMMARY

Forage is an intermediate good to the production of the final output, such as wildlife, livestock, wild horses and burros. The demand for the final output, the herbivore, can be used to derive the future demand for range forage. The demand for livestock is a function of society's demand for market commodities such as meat, hides, wool, tallow, and secondary products. The most significant demand for livestock is meat.

The demand for meat is a function of export demand and United States consumption. United States meat exports were less than 1.5% of the total meat supplies in 1985. The international meat trade is projected to grow slowly, with many countries seeking self-sufficiency in meat production. The implication is that the demand for meat in the United States will be primarily a function of domestic consumption. The domestic demand for beef or lamb meat is related to consumer tastes and preferences, disposable income, changes in human population size and age distribution, and the relative prices of alternative foods, particularly other meats.

The cause for recent shifts and declines in per capita meat consumption is uncertain. Changes in sociological factors such as a more health conscious public, or economic factors such as record high levels of meat production will require a few years of data before shifts in consumer demand are quantified. Population and income projections will determine the future demand for meat production.

The supply of meat is determined by the cost structure of production. The price of beef cattle or sheep depends upon the interactions between the supply and the demand of meat. The forage demand for livestock production depends on the technology associated with livestock production, the prices of alternative feeds, the interactions of forage with other inputs, and the price of livestock. The availability of grazed forages is critical in two segments of the beef cattle industry: breeding herds and stocker cattle production. For the sheep industry, the breeding herds are dependent upon grazed roughages.

Grazed forage consumed by beef cattle and sheep is produced on deeded nonirrigated rangeland and pasture, publicly-owned grazing land, deeded irrigated pasture, and from crop residue. The relative contribution of each forage source reflects the type of operation, type of animal, and the regional land use. Public grazing is more important in the West, whereas crop residue is more important in the East.

Forage demand could be greater if the lean beef production required only forage to finish animals. The recent trends are for a shorter period in the feedlot, which would imply less grain demand, rather than an increased forage demand. If per capita beef consumption increased and the increase was toward lean meat, then the forage demand would be greater to meet the increased production of beef and lamb meat.

CHAPTER 4: FORAGE SUPPLY/DEMAND PROJECTIONS

For the present assessment, forage supply was projected from the future availability of grazingland and likely improvements in forage production. Demand for grazed roughages was determined from future livestock projections, and assumptions concerning the future distribution of forage sources. Many of the aspects about the production and consumption of forage prohibit a traditional market equilibrium model at the national level (as is used for timber). Factors affecting supply and demand of forage are often local and reflect an individual livestock enterprise (Chapters 2 and 3).

The supply/demand of livestock has been simulated in econometric models where livestock production interacts with other agricultural commodities (Boss et al. 1978). The projection horizon is a function of factors included in the model that determine the supply/demand of livestock. When meat production is represented by changes in livestock inventories and animal prices, the model is often used to project for short periods of time, 1 to 10 years. Long-term issues, such as the impact of land availability, technological improvement in the forage production, and the effect of this improvement on inventories of livestock, can not be examined in many of these short-term projection models (Salathe et al. 1982, Taylor and Beattie 1982). The National Interregional Resource and Agricultural Production model (NIRAP) analyzes meat production as a function of feed inputs aggregated at the national level (Quinby in press). By incorporating some aspects of the livestock production process, this model provides a long-term projection for meat production and has been used in previous assessments and appraisals (USDA Forest Service 1980, USDA Soil Conservation Service 1987c). The NIRAP model was used to project the national demand for meat and livestock production for the present assessment.

All projections of the future rest on a set of assumptions concerning the demographic and economic variables within society. The basic assumptions for the Range Assessment projections are presented in this chapter, followed by the supply and demand projections for forage.

BASIC ASSUMPTIONS

Population

In 1986, the United States population was 242 million, an increase of 100 million in the previous five decades. Over the next five decades, population growth will be slower than in the last 50 years, and the population is projected to reach 333 million by 2040. The decline in the annual growth rate, from about 1.1% in the 1970s to 0.2% in the 2030-2040 decade, reflects assumptions about declining fertility rates (Darr in press). These population projections assume a net immigration of 750,000 people per year, including an estimate for net illegal immigration.

The distribution of population growth will influence the demands and services needed within states and regions. The most rapid growth will occur in the Pacific Coast, the Southern, and some areas within the Rocky Mountain region. The age distribution of the United States population will shift during the projection period to a greater proportion of the population in the middle-age classes.

Per Capita Disposable Income

Disposable personal income is that income available for spending or saving. As such, this income is related to the general economic picture often described by the gross national product (GNP). In 1986, the GNP was more than five times the 1929 level. Analyses by Wharton Econometric Forecasting Associates indicated that by 2040, GNP will increase over four times that of the 1985 level (Darr in press). Within this economic environment, by 2040 disposable personal income will increase some 2.5 times the level of 1986 (Darr in press). This increase in per capita income implies that future populations will have a much greater purchasing power than today. Although this is critical in terms of the consumption of goods and services, the link between disposable personal income and the consumption of meat, as discussed in Chapter 3, has weakened. Increased personal income will also have impacts on other uses of the range resources, such as recreation.

Energy

The economic projections assume that while transportation, trade, and other services will grow slowly in terms of their share of the total economic activity, the United States will continue to produce large quantities of physical goods in the manufacturing and construction sectors. Thus large supplies of energy, minerals, and other raw materials will be needed to produce these goods. Oil prices (in constant 1982 dollars) rise from $12 per barrel in 1986 to $50 in 2020 and remain at this level through 2040 (Darr in press). For this assessment, conservation and development of alternative energy sources slow the rate of increase in energy prices. The 2020-2040 prices are assumed to be high enough to stimulate the development of alternative energy sources with implications for the demand for timber and timber products, especially fuelwood. For forages, government intervention is

assumed necessary to foster an energy industry utilizing forages as an input to energy production (Byington 1988). Thus, the development of alternative energy sources is not assumed to shift the demand for forages.

Institutional and Technological Change

Institutional changes, such as legislation for the reservation of land for wilderness, parks, and wildlife refuges, have occurred in the past, and have changed the use of rangelands (fig. 23). Legislation has affected the management of rangelands in terms of providing forage and habitat for wild horses and burros, endangered or threatened plant or animal species, and wildlife (table 13). Technological changes have also impacted the production of forage (tables 11, 12, and 23). These institutional and technological changes are assumed to continue in the future and the effects of these changes will likely be similar to those that have occurred in the past. Many of these changes are implicit in the historical data used in preparing the projections. Other assumptions are explicitly described in the analysis.

Productivity within the Agricultural Sector

Productivity of the agricultural sector is expected to grow at 1.6% per year, with increased productivity of feed grains averaging 1.7% in 1990-2000 and 1.2% in 2000-30 (Quinby 1985). Increased productivity of rangeland is projected to grow at 0.7% per year (Pendleton and Hetzel 1983). This increase is based on the assumption that rangeland productivity would grow at this rate if the currently available technologies were implemented on the Nation's rangeland. Technology currently available to increase rangeland productivity includes undesirable plant and insect control, interseeding, fertilization, and improved animal management through grazing systems and fencing (tables 11, 12, 24, and 25). The factor most severely limiting increased productivity on rangelands is capital investments, including short-term investments for maintenance of productivity. Under an unfavorable economic situation, this annual increase could drop to 0.3%. A high demand for range products could increase the price received for those products. This return would enable and encourage the producer to make greater than expected capital investments in range improvements such that the annual increase could rise to 1.2% (Pendleton and Hetzel 1983). For this assessment, the median estimate was used to project likely future increases in forage production. This projection does not include the likely increases in beef and lamb productivity (table 25), nor does it include additional developments not currently available for forage production (table 12).

Trade Assumptions

A number of studies have projected that future world agricultural trade will likely grow more than in 1982-83 but less than in the boom years of the 1970s (Food and Agriculture Organization 1983, Quinby 1985, Sanderson 1984). Several factors will limit exports: increased production in foreign importing countries, debt problems in many developing countries, volatility in currency exchange rates, and less than robust foreign economic growth. For this assessment, United States export growth is expected to grow 3% per year in the 1990s and 2% over the following decade; the strongest growth will be in the export demand for feed grains (Quinby 1985).

Rising demand from population growth or increased income levels will stimulate meat production worldwide. The demand for this meat, however, will be met with intensive poultry and pig production, or rural and pasture-based ruminant production within each country. The implication to the United States meat industries is that the international trade in meat will probably not improve over the short-term. The demand for meat in the United States will be primarily a function of domestic demands, not rising exports.

Beef, Veal, Lamb, and Mutton Consumption

In 1950, per capita pork consumption was 64.4 pounds, beef and veal, 57.4 pounds, and poultry, 24.7 pounds (Lipton 1986). Thirty-five years later, beef and veal consumption (edible weight) was more than 80 pounds, poultry, 69 pounds; and pork, 62 pounds (fig. 43). By 1985, total meat consumption had risen 165% from 1950 levels (Lipton 1986). This rise in total meat consumption, primarily beef, was the basis for projections in the early 1980s that beef, veal, lamb, and mutton consumption would rise 11% by 2030 (USDA Forest Service 1980). Increases in meat consumption did not continue into the 1980s and by 1987, per capita meat consumption (beef, veal, lamb, mutton) had dropped below the high levels seen in the 1970's (fig. 43). Future projections suggested only a rise from 108 pounds in 1982 to 111 pounds (carcass weight) by 2030 (table 27) (USDA Soil Conservation Service 1987c). For this assessment, per capita consumption of beef and veal is assumed to remain at 110 pounds (carcass weight) and lamb and mutton at 2 pounds (carcass weight) in 1987-2040 (fig. 45).

DERIVED DEMAND FOR FORAGE

The demand for forage is a function of the demand for beef cattle and sheep. Incorporating the assumptions outlined above, supply/demand projections for beef, veal, lamb, and mutton were made with the NIRAP model. Factors affecting the demand for meat include future population levels, per capita food demands including meat, and net exports. Factors affecting the supply of meat include increases in crop productivity, feed grain production, and prices paid by farmers. An equilibrium solution of price-quantity combinations of agricultural products including meat was determined by the NIRAP model (Quinby 1987, Miranowski 1988). A national

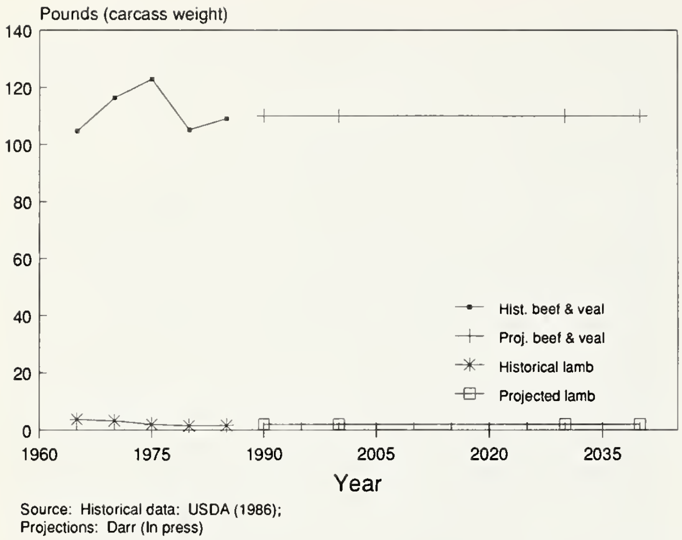


Figure 45.—Per capita consumption of beef, veal, and lamb: historical and projected, 1965-2040.

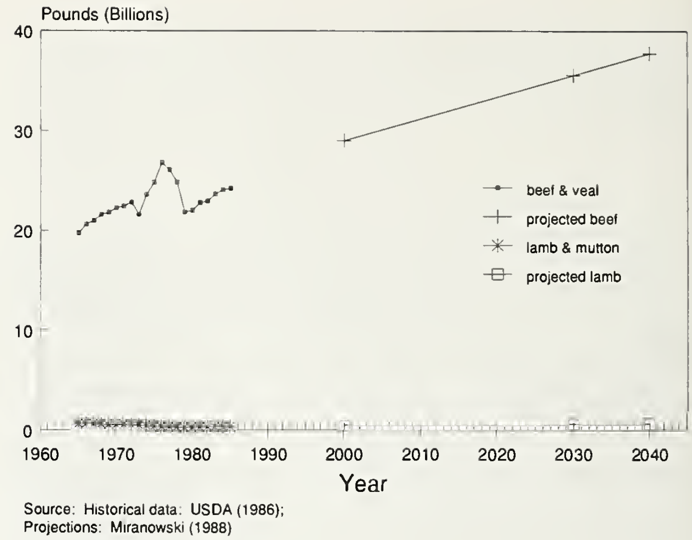


Figure 46.—U.S. meat production by animal type (carcass weight): historical (1965-1985) and projected (2000-2040).

feed/meat production relation is used in the NIRAP model to calculate livestock production. The regional relations between forage sources, availability of land, and factors in forage production are not examined in the NIRAP model and for this assessment, projections of meat production from the NIRAP model were disaggregated to the regional level based on historical distributions of livestock (Chapter 3). The derived demand for forage, based on regional historical patterns of grazed forage consumption, was then determined.

Meat Projections

Beef and veal production is projected to increase throughout the projection period and by 2040 will be 56% above the 1985 levels (fig. 46). This increase in beef and veal production reflects the 39% increase in population, the 260% increase in per capita disposable personal income, a 4% increase in meat exports, and a 2% decrease in meat import (resulting in a greater demand on domestic production) over the projection period. The 1985 base year value for per capita consumption of beef and veal was 109.1 pounds, thus per capita consumption rose slightly over the projection period. This per capita rise and population growth resulted in a 147% rise in the demand for meat. The effect of per capita disposable income on meat consumption is less than during the 1970s, but the significant rise in per capita income in the last projection period results in beef consumption slightly above 110 pounds. Even with these projected increases, beef and veal production do not exceed historical production values until 2000 (fig. 46).

Lamb and mutton production is a small component of the total meat production in the United States and as such, is difficult to project with any certainty. Projections from the NIRAP model suggest a very optimistic picture for lamb and mutton production with increases of 85% over the projection period to 660 million pounds by 2040 (fig. 46). Actual production for 1985 was 357 million pounds (U.S. Department of Agriculture 1986). Sheep inventories and lamb and mutton consumption records suggest an historical decline and a recent flat trend in consumption (figs. 34 and 43). The variability of historical levels of sheep were used to bound the optimistic projection.

Livestock Inventory Projections

The NIRAP meat projections (fig. 46) were used to estimate future livestock inventories (Gee and Madsen 1988). The historical variability in livestock inventories in 1965-86 reflects technological and social changes in meat and livestock production, including cattle cycles. The assumption is made that these factors will continue to influence livestock production to the same extent in the future. The certainty with which a projection can be made decreases in time, thus the upper and lower limits for the projections of livestock inventories were computed using 1 standard deviation from the mean for 1990, and 3 standard deviations for 2030 and 2040 (Gee and Madsen 1988).

Beef cow inventories in 2040 are projected to be 55 million, a 56% increase over 1985 inventories (fig. 47). Beef cow numbers are not expected to exceed the historical peak until after 2000, and the 2040 inventory is only 21% above the 1975 peak. Based on the historical variability in livestock inventories, the upper bound for the 2040 projection was 64.5 million beef cows and the lower bound, 45.6 million cows. Given recent trends in per capita consumption of meat, an aging human population, a flat export demand, and competitive substitutes for beef, it is unlikely that the beef cow inventories will move toward the upper bound, and more likely these inventories will be between the projected and lower

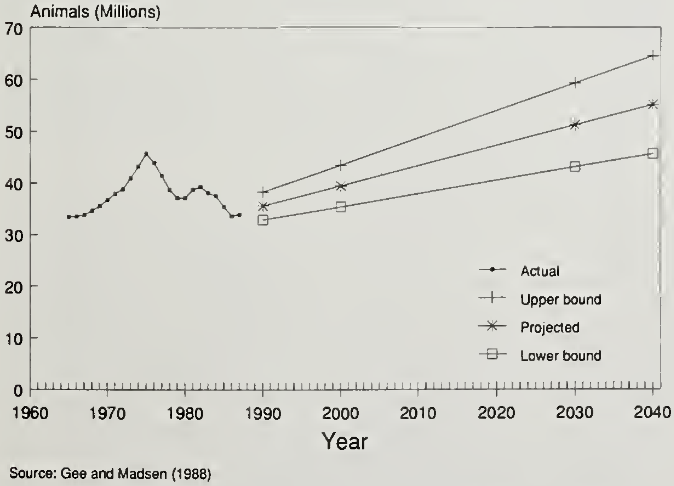
bound estimates (fig. 47). For this analysis, the projected inventory is used to determine the future forage demand from beef cattle.

Breeding ewe numbers were projected to be 18 million by 2040 or more than twice the 1985 inventory of 7.2 million (fig. 48). Although this projection is less than historical peaks (fig. 34), the decline in ewe numbers since 1965 would suggest that this projection is optimistic. The volatility of ewe numbers produces a wide upper and lower bound projection (fig. 48). Human population increases alone are insufficient to sustain a large increase in demand for lamb and mutton, and per capita consumption of lamb has declined (fig. 43). For this analysis, the lower bound will be used as the likely future for sheep inventory numbers and to determine the forage demand.

National Aggregate Forage Consumption Projections

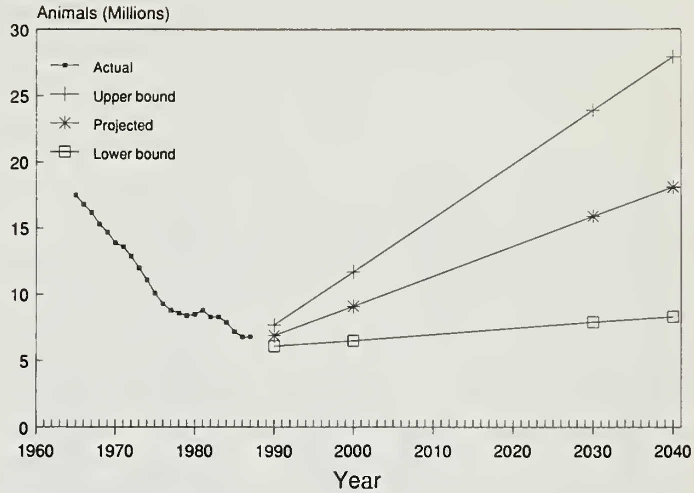
Aggregate grazed forage consumption was based on the above projected livestock numbers and an estimated per animal grazed forage demand from U.S. Department of Agriculture, Economic Research Service (ERS) budgets (Gee et al. 1986a, 1986b). Historical consumption of forage by beef cattle and sheep for 1980-87 and projections for 2000 through 2040 are shown in table 28. Upper and lower limits are based on the historical variability in livestock numbers (figs. 47 and 48). The upper and lower bounds of the forage demand projections for cattle differ from the mean (575.8 million AUMs) by 16%, whereas the upper and lower bounds for sheep forage demand are much greater at nearly 50% of the mean (35.5 million AUMs). This variability in livestock forage demand is a reflection of the decline in sheep numbers in 1965-85 and the variability in cattle numbers through two cattle cycles (fig. 34).

For this assessment, the projected future demand for forage by livestock is the sum of the projected demand



Source: Gee and Madsen (1988)

Figure 47.—January beef cow inventories (1965-87) and projection to 2040.



Source: Gee and Madsen (1988)

Figure 48.—January breeding ewe inventories (1965-87) and projections to 2040.

for cattle and the lower bound for sheep (total in table 28, fig. 49). These projected values reflect a slowly increasing demand for forage, driven by human population growth and, to a lesser degree, per capita consumption, exports, and imports. By 2040, total forage demand of 665 million AUMs represents an increase of 54% over the 1985 value for beef cattle and sheep (table 28). Based on this projection of demand, the forage supply would need to increase at least 1% annually.

These projections do not include other livestock, such as goats, horses, and hogs. The grazed forage demand for these livestock is small compared with beef cattle, and is assumed to remain small over the projection period. Wildlife projections are given in Flather and Hoekstra (in press) and the implications of this wildlife forage demand to range vegetation is discussed in Chapter 5 in the present report.

FORAGE SUPPLY

Supply projections for forage were based on the future availability of grazingland and the future technological improvements in forage production. The future land area needed for cropland and urban land are determined in the NIRAP model; the remaining land area is allocated to pasture, rangeland, and forest land based on historical trends. This land area projection for rangeland was then adjusted to account for the future implications of the Food Security Act. The likely future technological improvements were coupled with this land area projection to determine the future supply of forage.

Rangeland Area Projections

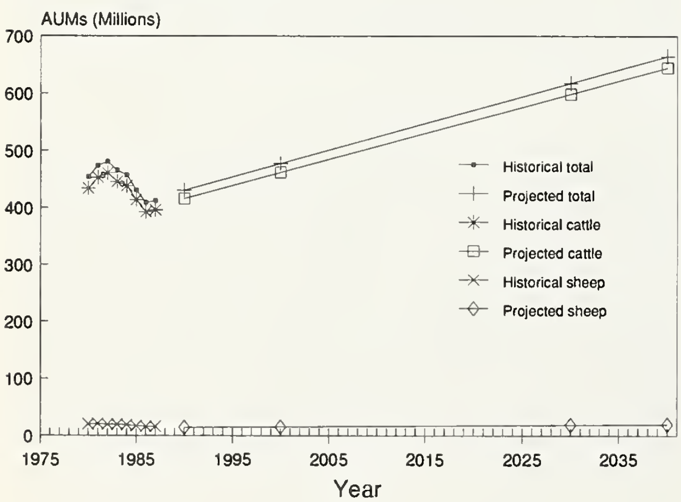
Projections made by the ERS indicate that pasture and rangeland area will increase slightly (1%) over the projection period (Miranowski 1988). The conversion of

Table 28.—Forage consumption for beef cattle and sheep (million AUMs) during 1980-87, and projections for 2000-40 in the United States.

Year	Beef Cattle			Sheep			Total
1980		434.0		20.4			454.4
1981		452.7		21.1			473.8
1982		460.9		19.9			480.8
1983		445.6		19.9			465.5
1984		438.5		19.0			457.5
1985		413.9		17.3			431.2
1986		392.8		16.3			409.1
1987		396.3		16.3			412.6
	Low	Projected	Upper	Low	Projected	Upper	Projected
2000	414.2	462.1	508.9	15.6	21.8	28.1	477.7
2030	504.3	599.0	693.8	19.0	38.2	57.4	618.0
2040	533.5	644.7	754.6	19.9	43.4	67.0	664.6

Source: Gee and Madsen (1988).

rangeland to cropland is assumed to be lower in the future than the extensive conversions of the 1970s. The future demand for cropland is assumed to be less because of reduced agricultural exports, increased growth efficiencies in feed grains, and increased feeding efficiencies in livestock. The increased production efficiencies will contribute to a decline in the acreage planted to feed grains and unplanted acres will return to a permanent cover of herbaceous vegetation. The decline in irrigated cropland, particularly in the West (Guldin in press, USDA Soil Conservation Service 1987c), also reduces the demand for conversion of rangeland to cropland in the future. These projections reflect the recent USDA Appraisal projections where future cropland used for crop production declines significantly (USDA Soil Conservation Service 1987c).



Source: Gee and Madsen (1988)

Figure 49.—Projected consumption of grazed forages by cattle and sheep, 1980-2040.

The ERS land area projections did not include any effect of the Food Security Act of 1985. The conservation provisions in this Act could potentially impact land use on cropland and rangeland. The "swampbuster" and "sodbuster" provisions of the 1985 Food Security Act are expected to slow the conversion of highly erodible rangeland to crop production. The conservation compliance provisions of the 1985 Food Security Act are also expected to reduce the conversion of highly erodible rangeland to cropland. The Conservation Reserve Program (CRP) will place nearly 45 million acres of cropland into permanent vegetation. About 85% of the acreage currently enrolled in the CRP has been planted to grasses (Dicks et al. 1988). At the end of this 10-year program, the vegetation cover on most of the western CRP lands will likely be native or introduced grass species. Over 65% of the grass plantings thus far have been tame (introduced) grass species. The CRP land planted to introduced grass species will probably remain in grass cover and be managed extensively. If fields seeded with grass species proceed through natural succession, range vegetation would be the likely vegetation type in the Rocky Mountain and Pacific Coast regions, and the states of Texas and Oklahoma in the Southern region. Because the future demand for cropland appears less than in the past, it is assumed that land placed in the CRP would not return to crop production.

In the western regions (Rocky Mountain, Pacific Coast, and the states of Texas and Oklahoma), it is assumed that by 2000, all CRP land will be managed as rangeland unless originally planted in trees. Western CRP lands planted to introduced grass are assumed to be managed as rangeland by 2000. From 2000 to 2040, this former set-aside land is assumed to remain in rangeland and be available for livestock grazing. In regions where forest is the climax and pasture is a viable economic alternative land use (Northern and Southern), the CRP land remains as pasture, unless originally planted into trees. At the national level, this land area projection represents a 5% increase in rangeland area from 1985 to 2040 (table 29).

The largest increases in rangeland area occur in the Rocky Mountain and Southern (Texas and Oklahoma) regions.

Increased Productivity from Technology

Productivity of rangeland was assumed to increase 0.7% per year during 1987-2040. Thus, by 2040, forage production per acre will have increased 47% over 1985 levels from the implementation of already developed technology.

Projections for Future Range Forage Production

Private Land

The supply of forage from private lands is the result of decisions made by individual enterprises. Those decisions rely on the availability and cost of land and technology. Based on the above projections for these inputs, the supply of forage from private lands in 2040 is projected to increase by 52% over the 1985 levels.

Public Land

Projections for the amount of grazing to be supplied from National Forest System (NFS) lands, given the current and projected demand, were obtained from USDA Forest Service, Regional Offices 1-9 (1987, 1988). Overall, AUMs permitted to graze on NFS lands are projected to drop in 1990 and then gradually rise slightly over the 1986 level by 2040 (table 30). These increases are greatest in the California region (Region 5) at 17%. Declines are projected for the Southwest (Region 3) and the Southern region (Region 8) (table 30). The amount of grazing to be supplied from the Bureau of Land Management (BLM)-administered lands will likely be a continuation of the current levels (Peterson 1988). Grazing on NFS and BLM-administered lands dominate the public forage supplies and projections of supplies from other public lands, such as state or local, are assumed to remain at

Table 29.—Rangeland area projections (1,000 acres) by assessment region.

Year	Rocky Mountain	Pacific Coast	Southern	Northern	Total U.S.
1985	413,396	240,775	115,754	426	770,351
2000	440,227	240,810	127,531	340	808,907
2010	439,382	241,751	128,335	290	809,758
2020	438,367	242,388	128,950	249	809,953
2030	437,346	243,148	129,517	220	810,232
2040	436,356	243,643	130,024	196	810,219

Source: 1985, Bones (1989), projections based on Miranowski (1988) and the assumption that cropland placed in the Conservation Reserve Program would remain in permanent cover.

Table 30.—National Forest System historical records (1980-1986) and future projections (2000-2040) for livestock grazing (1,000 AUMs).

Year	National Forest System Region[1]								Total
	1	2	3	4	5	6	8	9	
1980	1,408	2,157	2,330	2,307	544	719	225	67	9,757
1981	1,394	2,166	2,370	2,316	529	724	231	69	9,799
1982	1,393	2,172	2,428	2,288	567	745	229	80	9,902
1983	1,391	2,190	2,531	2,311	596	741	234	78	10,072
1984	1,401	2,214	2,513	2,252	608	741	247	77	10,063
1985	1,400	2,170	2,504	2,357	621	745	248	78	10,124
1986	1,400	2,151	2,510	2,355	592	748	239	78	10,073
2000	1,401	2,199	2,100	2,300	620	779	200	78	9,677
2010	1,406	2,290	2,120[2]	2,300	625	777[3]	200	78	9,796
2020	1,411	2,315	2,160	2,300	630	774	205	78	9,873
2030	1,425	2,335	2,200	2,300	655	774	210	78	9,977
2040	1,440	2,360	2,240	2,300	725	774	210	78	10,127

[1]*Assessment Regions correspond to the following National Forest System region: Northern Rocky Mountain, 1, 2, 4; Southwest, 3, California, 5; Pacific North, 6; Northern, 9; Southern, 8.*
[2]*Interpolation between 2000 and 2040.*
[3]*Interpolation between 2000 and 2020.*
Source: USDA Forest Service, Regional Offices 1-9 (1987, 1988).

current levels to 2040. The future supply of grazing from public lands will rise less than 1% by 2040.

SUPPLY/DEMAND COMPARISONS AT THE NATIONAL LEVEL

If forest and rangeland continue to contribute the same relative amount of forage to the total supply, then forage production on forest and rangelands will have to increase 54% by 2040 (fig. 50). This increase represents the demand on all sources of grazed forages (table 10). The area of rangeland is projected to increase by 5% by 2040 and the assumed technological increases in forage production result in a projected increase of 47% in forage supply. Thus forage supplies would appear to nearly meet the derived demand for forage (fig. 50).

The relatively flat projection for the supply of public grazing contrasts with the projected increase in forage demand (54%). Thus, in terms of total forage consumption, the relative contribution from public lands will decline. This projection implies that these additional forage demands, if met, will need to be supplied from the private sector. The amount of rangeland in the private sector is projected to increase by 5%. Much of this land will be former cropland where the productivity may be higher than the average for rangeland. Permanent plantings for the current set-aside programs, however, could have significant implications on the long-term supply of forage. In Oklahoma, native pasture produces only 50 pounds of beef per land unit whereas introduced pasture grasses produce 250 pounds of beef (Sims 1988a). Long-term maintenance costs of native versus tame pastures must also be considered. These forage differences will be critical in the determination of a land use offering the highest return on former CRP lands.

These supply/demand comparisons of forage are based on the demand for livestock production only and do not consider other range outputs that use forage, such as wildlife or wild horses and burros. A comparison of the future wildlife projections in western United States with these livestock projections is made in Chapter 5.

ALTERNATIVE SCENARIOS OF SUPPLY/DEMAND

Land Area Projections Based on Historical Trends

Historical forces affecting the use of rangeland have included: (1) demand for crop products; (2) withdrawal of land for recreational, wildlife, and environmental purposes; and (3) withdrawal of land for urban areas. Conversion of pasture and rangeland to other uses is not likely to increase dramatically in the future (O'Brien 1988). Future increases in crop productivity and declines in crop exports will result in a lower demand for cropland. The recent USDA Appraisal projects that cropland used for crop production will decline significantly in the future (USDA Soil Conservation Service 1987c). More than 350 million acres were in crop production in 1982, and by 2030, the Appraisal analysis suggests that only

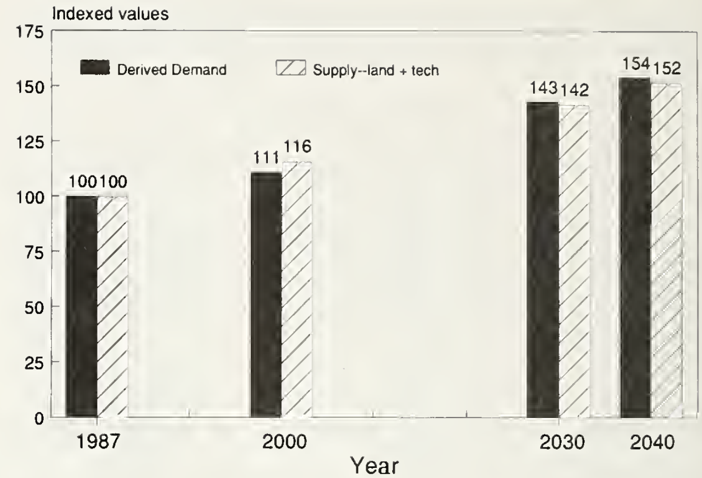


Figure 50.—Forage supply/demand projections indexed to 1987.

218 million acres will be needed to supply the crop production needs (USDA Soil Conservation Service 1987c). This analysis implies that potentially 152 million acres of cropland could sit idle, move into set-aside programs, or be converted to alternative land uses which bring a higher profit such as urban land.

The Appraisal projections were based on several assumptions concerning land use shifts (USDA Soil Conservation Service 1987c): (1) consumer demand for less meat and a leaner meat product will lower the demand for feed grains; (2) reduced exports place less demand for cropland; and (3) few conservation measures mitigate wind erosion, notably highest in the Great Plains. In the Appraisal analysis, cropland with the lowest profit per acre was identified as those acres which would be removed from crop production to reduce excess production and to meet the Conservation Compliance provisions in the Food Security Act of 1985. Sheet and rill erosion per acre is greater in regions other than the Great Plains, but attacking erosion by reducing acreage with the smallest profit margin per acre means that cropland comes out of production in areas such as the Great Plains. Less than 40% of the available cropland in the Great Plains is projected to be in production by the year 2000 (USDA Soil Conservation Service 1987c). Thus, the future uses of the projected idled cropland will depend on the alternative land uses available within each region.

Government crop-acreage control legislation has and will continue to have a significant impact on the use of rangelands. The long-term use of land in the most recent acreage-control program, the CRP, is uncertain. This land, if it remains in permanent vegetation cover, could increase forage supplies for wild and domestic herbivores. As assumed in the above land area projection, nearly 35 million acres from the CRP will remain in the grazingland base at the end of the program in 10 years. At the national level, the decline in pasture and rangeland area has been 0.33% per year over a period during

which cropland acres were in high demand (1969-1982).[15] Over the next 10 years, the historical loss of pasture and rangeland would mean a loss of 23 million acres. Thus, if the CRP acres (over 35 million acres) remained in grass and shrub cover, the national total of pasture and rangeland area would remain relatively unchanged for at least two decades into the projection period.[16] If rangeland area continued to be lost at the historical rate over the 1985-2040 projection period, and the CRP acres returned to cropland, the annual loss of rangeland would be 2.54 million acres and by 2040, the Nation's rangeland area would be 630 million acres, down from 770 million acres in 1985.

At the regional level, the current distribution of enrolled acres can be used to estimate the final distribution of CRP lands. The potential CRP enrollment acres in each region could be: Northern Rocky Mountain, 18.0 million; Southwest, 0.9 million; California, 0.3 million; Pacific North, 2.6 million; Northern, 8.8 million; and Southern, 12.4 million. If the historical annual losses of pasture and rangeland continued over the next 10 years, the following loss in total rangeland area by region would occur: Rocky Mountain (NR + SW), 12.0 million; Pacific Coast (PN + CA), 0.8 million; Northern, 9.2 million; and Southern, 1.5 million. Thus, in all Assessment regions, more land would be converted into permanent vegetation cover from CRP than would be removed from pasture and rangeland use over the same period. If the rapid land conversions of 1969-75 reoccurred, however, pasture and rangeland area in the Northern and Southern regions would decline. Historical data on regional conversions of forest grazing were unavailable.

Previous government set-aside programs have resulted in little acreage remaining in permanent cover. During periods of high crop prices that followed the set-aside programs, acres were plowed up and put back into crop production (Bartlett and Trock 1987). It is difficult to determine the future consequences of the entire Food Security Act of 1985.

Shifts in the Regional Supply of Forage

Regional forage consumption patterns differ across the United States. Forage from deeded non-irrigated land is the mainstay of livestock operations in the Southern and Northern regions whereas forage from a variety of sources is important in the western United States (table 18). The future supply of forage from public lands will affect the forage demand differently across the regions.

If the relative distribution of different forage types were to remain the same as the distribution in 1985 (table 18), all feed sources would need to expand by 40% or more to meet the projected demand in 2040 (table 31). Beef cow inventories at the historical peak in 1975 were 29% greater than the 1985 inventories, suggesting that the forage base has the ability to expand to meet a 29% increase in demand. Crop residues are currently in surplus, and economic incentives could overcome the management problems associated with the efficient use of this feed type (Gee and Madsen 1988). Expansion of irrigated pasture seems unlikely, because of rising costs of water and increased demand for water by urban areas. The historical trends in permitted grazing on public lands suggests slight or steady declines in grazing. These possible shifts in terms of the distribution of forage sources, if the expected demand is to be met, will differ by region.

Shifts in the regional supply of forage were analyzed with the following assumptions about the future distribution of forage: (1) a decline in grazed forage from public lands (NFS and BLM), based on trends during the last 10 to 15 years[17] (Gee and Madsen 1988); (2) irrigated grazing not expanding beyond 1985 levels; and (3) grazing of crop residues not expanding beyond 1985 levels. Assumption 2 reflects the premise that further expansion of irrigated pasture would be at the expense of more profitable cash crops, and the future costs of producing irrigated pasture will probably rise in relation to increasing water costs. Because water supplies are increasingly being sought by urban areas in the arid west, irrigation water supplies will continue to decrease, and shift agricultural water to only the most profitable crops. Assumption 3 is based on the premise that although many acres of crop residue go unused annually, the location and lack of fencing and water raise practical concerns in using this source of feed (Gee and Madsen 1988).

Under these assumptions, several feed sources decline in their relative contribution to the total forage, placing a greater demand for forage from deeded pastures (table 31). By 2040, irrigated grazing and crop residue are supplying the same amount of forage as in 1985 and public grazing has declined to 34% of the 1985 level. Total forage demand has increased 54% over the 1985 levels. Thus, the contribution that deeded nonirrigated forage must make to the total forage supply would have to increase by 71% over the 1985 contribution to meet these expected demands.

SUMMARY

Projections presented in this chapter suggest that the supply of forages at the national level will nearly

[15]*Frey and Hexem (1985) reported 890 million acres in 1969 and 820 million acres in 1982 of grazingland—forest, pasture and range. This 70 million acre loss represents an annual loss of 0.6%, or 5.3 million acres. When only pasture and rangeland acres are examined, 692 million in 1969 and 662 million in 1982, the annual loss is 0.33% or 2.3 million acres per year.*

[16]*When the declines in forest grazing are included with pasture and rangeland, the annual decline in grazingland area is 5.3 million acres, and over 10 years, this represents a decline of 53 million acres in the grazingland base. Forest grazing, however, has declined for a number of reasons, including changing management practices which exclude livestock grazing. Thus, although the CRP land will return acres to forest land, changes in management on forest land could impact forest grazing much more significantly.*

[17]*Gee and Madsen (1988) reported that the decline in BLM grazing was nearly 5% per year during 1965-85 and was less than 0.2% on NFS lands at the national level. These are based on historical trends, not planning projections.*

Table 31.—Projected consumption of grazed forage (million AUMs) by type of forage, 2040, by assessment region in the United States.

Type of forage	NR	SW	CA	PN	SO	NO	Total
			Continuation of historical trends[1]				
Deeded grazing land							
Nonirrigated	157.8	10.3	33.4	31.2	280.0	72.4	585.1
Irrigated	6.7	0.2	4.7	6.7	1.2	—	19.5
Public grazing land	25.5	5.4	3.1	3.2	11.0	—	48.2
Crop residue	13.5	0.3	2.7	2.2	11.5	5.1	35.3
Total	203.5	16.2	43.9	43.3	303.7	77.5	688.1
			Reduced forage substitutes[2]				
Deeded grazing land							
Nonirrigated	181.8	12.3	40.1	39.9	290.7	72.6	637.4
Irrigated	4.2	0.2	1.9	2.2	0.8	—	9.3
Public grazing land	9.2	3.4	0.8	0.5	5.2	—	19.1
Crop residue	8.3	0.3	1.1	0.7	7.0	4.9	22.3
Total	203.5	16.2	43.9	43.3	303.7	77.5	688.1

[1]*Both analyses reflect the median projection for sheep and cattle.*

[2]*Projections based on the following assumptions: (1) Deeded nonirrigated rangeland is assumed to compensate for reductions in forage from different sources. (2) Supplies of public grazing land by 2030 are expected to drop an average of 82% below 1985 levels. This is based on projection of historical trends in AUMs for 1977-85 for FS and 1970-86 for BLM grazing. (3) It is assumed that there is no expansion in irrigated pasture production above 1985 levels. (4) It is assumed that crop residue consumption will stay at 1985 levels.*

Source: Gee and Madsen (1988).

meet the demand for grazed forages in 2040 if certain assumptions are met. The most critical of these assumptions is the continued increases in forage production on forest and rangelands, resulting from implementation of existing technology. Recent analyses of range improvement practices, as discussed in Chapter 3, suggest that an improved livestock market will be necessary for the assumed application of this technology to occur. A critical assumption on the demand side is the constant per capita consumption for beef, veal, lamb, and mutton. A decline in per capita demand will, consequently, cause a decline in the demand for grazed forages. In addition, a shift in preference for leaner meat may cause a shift in the relative contributions of feed in the livestock production process. As discussed in Chapter 3, this feed shift may increase forage demand.

Projections at the regional level suggest that shifts in the relative contribution of forages will occur. Most notably is the decline of the relative contribution of public grazing. This decline will necessitate increased forage production on private lands if the projected forage demand is to be met. Projections of increased rangeland in the private sector could contribute to an increased supply, but forage production must also increase on a per acre basis to meet this derived demand.

The subtle relations between land available for forage production, production factors within regions, and shifts in livestock productions between regions were not analyzed in this assessment. This analysis assumes that cropland conversions similar to the late 1970s will not result in a resurgence of "sodbusting." Nor is it assumed that urbanization will dramatically affect the national supply of rangeland.

CHAPTER 5: SOCIAL, ECONOMIC, AND ENVIRONMENTAL IMPLICATIONS OF SUPPLY/DEMAND COMPARISONS OF FORAGE

INTRODUCTION

Projections made in Chapter 4 imply certain social, economic, and environmental conditions in the future. The desirability of this future depends on society's values concerning the range resource. These values encompass social, economic, and environmental concerns of individuals and groups. As future changes in society's values cannot be foreseen, this discussion of the implications of the projections will necessarily be based on the values that society historically has held and currently holds for the use of rangelands. These historical and current trends will be used to project probable future trends in the values society assigns to the uses of rangeland. This examination of the likely future social, economic, and environmental conditions sets the stage for describing the obstacles and opportunities to managing rangelands (Chapter 6).

SOCIAL IMPLICATIONS

Social Implications Defined

Held values, ideas held by an individual about something, regulate preferences that function to assign relative value to objects (Brown and Manfredo 1987). Society's held values about the range resource can be categorized into cultural, societal, psychological, and physiological subcategories. Cultural values are ideas and thoughts that make up a culture (Brown and Manfredo 1987) and might be exemplified with respect to the range resource in the value of the livestock business as a way of life in the western United States (Bartlett 1986, Pope 1987). Societal values are defined in terms of social relationships among people. The community focus and the social dependence among western ranchers described by Erhlich (1985) are examples of societal values. Psychological values are related to the benefits that an individual perceives from the object of value (Brown and Manfredo 1987). Springtime hikes to see alpine flowers, birding trips to the grasslands, or knowing that bison or wild horses exist or that endangered plants have protected habitat reflect psychological values. And finally, physiological values may be associated with the range resource when interaction with the range resource through either work or recreation enhances health. Individuals might value the exercise associated with recreational hiking or horseback riding because of the health benefits, stress reduction, or a change of pace. The physical labor associated with operating a livestock enterprise might be valued because of its physiological benefits. Although the social value of range vegetation has not explicitly been determined, this value does influence the behavior of those who might use the land (Pope et al. 1984b). Society's ideas about the range resource regulate preferences that function to influence the use of rangeland.

Social Implications of Projections

The projected futures for range, wildlife, water, timber, and recreation imply increased demand for these resources and an increased use of forest and rangelands (Chapter 4 this assessment, Cordell in press, Flather and Hoekstra in press, Haynes in press). The public's increasing interest in water quality will focus attention on the management of rangeland (Guldin in press). The social benefits of the range resource may be jeopardized with increased use and intensification of use unless proper management is implemented.

Livestock enterprises and livestock grazing on rangelands will continue to contribute to the social well-being of rural communities. The future intensification of rangeland use will change ranching as a way of life. The increased need to maintain viable ranching operations by marketing additional products, such as different meat products, wildlife, or recreational opportunities, will increase the interaction between ranching operations and urban dwellers. More opportunities will likely exist for urban dwellers to experience the range resource. Cordell et al. (1983) projected that the demand for primitive, semi-primitive, and roaded natural and rural areas will outstrip future population growth. The value of wilderness or habitat for threatened and endangered species within a functioning ecosystem has increased with the passage of legislation such as the Wild Free-Roaming Horse and Burro Act of 1971, and the Endangered Species Act of 1973. This value is often held by people who may never experience the resource directly.

Social values influence the allocation of forage to wildlife, wild horses and burros, and livestock. Many different views exist concerning the use of rangelands by grazing animals. The extremes might be characterized by those who feel that all resource damage is linked to livestock grazing, and those who feel that rangelands should be managed for a single use, livestock grazing. Pressure exists to remove livestock from public lands. Recent concerns about chemicals in the environment have shifted the emphasis in vegetation management to biological control methods. The role that livestock have in vegetation management will be difficult to determine in an atmosphere demanding livestock removal from

public lands. The perception that rangeland health has deteriorated primarily from livestock grazing will be heightened in a future where demand for more wildlife habitat, wild horses and burro habitat, and threatened and endangered plant and animal species are cast up against increased livestock production on forest and rangelands.

ECONOMIC IMPLICATIONS

Economic Implications Defined

Economic implications are a special case of social implications and concern the monetary aspects of range forage production. Because it is difficult to assess the value of vegetation to uses such as wild horses and burros, or threatened and endangered species (Bartlett 1986), economic implications traditionally have been limited to a valuation of range forage for livestock. Forage for domestic grazing is valued on the site and at the margin (Bartlett 1986) and will vary with different enterprise structures. To provide sufficient information to compare other uses of forage, an understanding of the joint production of different animal species using the same resource base is necessary but little progress has been made toward this understanding. This situation is complicated further by uses such as the harvesting of native plants, so the plant, not an animal, is the product. Ultimately the monetary valuation of range vegetation to produce this diverse mix of outputs must be determined to examine resource tradeoffs. In the past, most of these uses were marginal, that is, did not determine the use of large areas of rangeland. In a future demanding more outputs from forest and rangelands, the economic valuation of different uses may determine rangeland use.

Economic Implications of Wildlife Use

The amount spent per hunter or fishermen for access to private lands has increased substantially since 1980 (fig. 51). On an annual basis, these increases vary from 7% for fishing to 12% for big game hunting. Access fees are a function of several factors including interpersonal relationships between the parties buying and selling the lease, the availability of game, services and facilities, and the general hunting experience. Although these factors make it difficult to precisely determine the value of wildlife, Pope and Stoll (1985) concluded in their study of Texas hunting access fees that the provision of services and facilities generally does not enhance the value of the hunting experience as much as access to a variety of game species on an adequately large parcel of land. Thus, this rise in access fees is an indication of an increase in the value of grazing in wildlife production. Although many success stories can be told on Texas rangeland, the viability of enterprises based on wildlife alone is still being explored. Unless future possibilities for economic returns from wildlife grazing increase, the

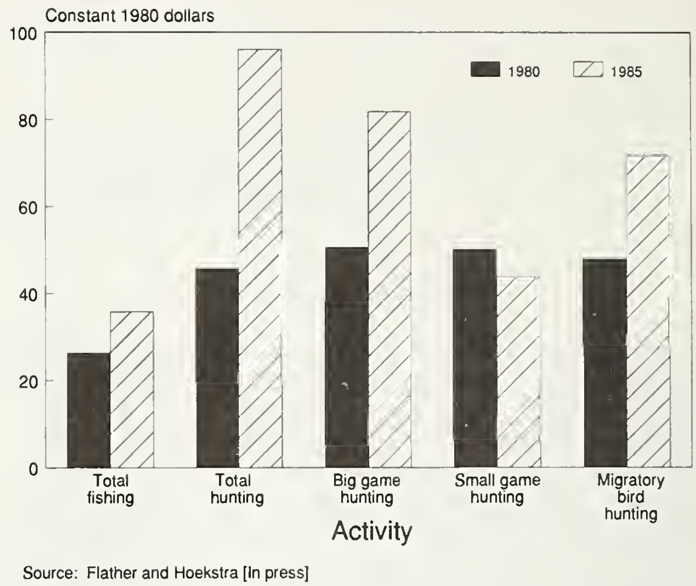


Figure 51.—Trend in private access fees (dollars per spender) for fishing and hunting, 1980, 1985.

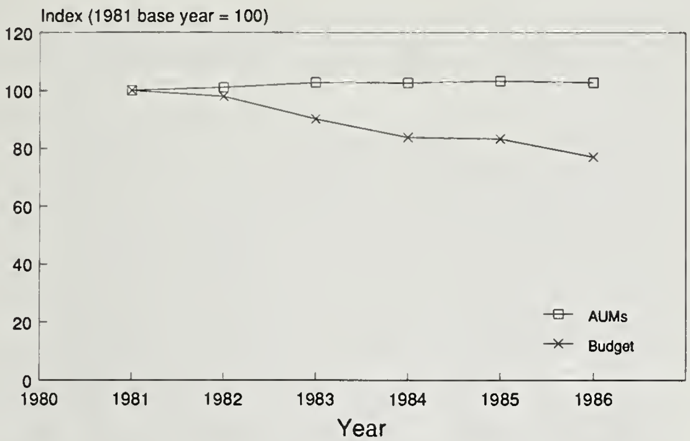
projected scenario implies a grazingland capable of supplying forage to livestock.

Economic Implications of Livestock Use

Improved range productivity, increased animal feeding efficiencies, and an increasing rangeland base contribute to an improved livestock industry in the future. Grazed forages remain at 80% to 90% of the total feed mix for livestock and it is unlikely that this relatively inexpensive source of feed will decline in the total feed mix in the future. Grazed forage is currently the cheapest source of feed and will likely remain inexpensive relative to other sources of feed. With the rangeland base increasing only 5% nationally, the projected forage supply relies on the implementation of currently available technology to meet the future demand for forage.

The distribution of sources for grazed forages will likely vary from historical patterns. Projections for Bureau of Land Management (BLM) permitted AUMs indicate a flat future supply, and projections for National Forest System (NFS) lands indicate a rise of less than 1% in permitted grazing (Chapter 4). The 1987 budget, in terms of constant dollars, for the NFS range management program has declined 22% since 1981. The number of AUMs authorized on NFS lands has remained nearly constant at around 10 million AUMs (fig. 52). The administration of these permits is only one responsibility of the range management program of NFS (USDA Forest Service 1987d).

Projected declines in irrigated lands will also impact the amount of pasture irrigated (Guldin in press, USDA Soil Conservation Service 1987c). The average area per grazing animal in western United States is lower than other parts of the United States (table 21) only because



NOTE.—Budget reported in constant 1981 dollars and is the net of inflation or deflation.

Source: Comanor (1988b)

Figure 52.—National Forest System range annual budget and authorized grazing use, 1981-1986.

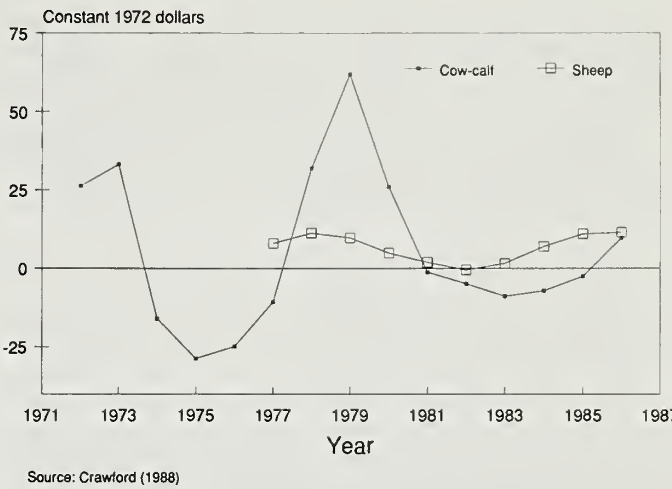


Figure 53.—Net returns on sheep and cow-calf operations: receipts less cash costs for 1972-1986.

of the high productivity of irrigated pasture and the accessibility of public grazing. Increasing costs of irrigating and the flat projected supply of federal grazing will result in herd reductions on those enterprises unable to implement necessary technology to improve forage production on their remaining land.

With the overall increase in forage demand, the decline in the relative share of public grazing and irrigated pasture implies that private lands will need to make up the difference in forage supply. Livestock operations unable to buy, grow, or otherwise obtain private forage for all seasons to replace public forage will not be part of the future growth in this industry. Thus, fewer livestock operations will be associated with public lands, with a potential decline in service industries associated with livestock production in these rural communities. This decline, however, is tied to social pressure to remove livestock from public lands, which is related to an increased demand for recreation and wildlife outputs. Services associated with recreation will likely increase in these rural communities.

At the state level, the future significance of this relative decline in federal forage can be seen in comparisons of the contribution that federal forage makes to the total feed mix within a livestock enterprise. Across the 13 western states, the median dependency level on federal forage is 23% (USDA Forest Service and USDI Bureau of Land Management 1986). In the southwestern states where animals can graze yearlong on federal lands, enterprises may get 36% (Nevada) to 44% (New Mexico) to 60% (Arizona) of their total feed from federal grazing. The northern Great Plains states depend on federal forage to supply from 11% (Montana) to 13% (Nebraska) of the total feed (USDA Forest Service and USDI Bureau of Land Management 1986). Amounts for other western states fall in between these examples. Even for livestock enterprises relying on federal forage for only 11% of the total feed mix, this amount may be difficult to replace as most of the enterprises utilizing federal forage would be in counties where most of the land would be managed by the federal government.

The recent volatility in beef cattle markets has spurred new approaches to diversifying a livestock operation (Heimlich and Langer 1988). Since 1975, livestock numbers have declined as the inventory adjusted to the relatively constant per capita demand for meat. The recent agricultural credit crisis has placed considerable stress on the livestock industry (Drabenstott and Duncan 1982). An estimate of the profitability of the beef cattle and sheep enterprises can be seen in cash receipts minus cash costs[18] (fig. 53). Profit volatility was very high for cow-calf operations in 1972-85. A profit has been made more often in sheep operations than in beef cattle since 1977 (fig. 53). Net cash returns for cattle operations were negative during 1981-84 when feed costs were high and cash receipts were low (Bowe 1987). When capital replacement costs are added into this equation, cattle operations were profitable only during 1978-80 over the entire 1977-86 period. In the past, cash shortfalls may have been weathered through rising land values or mineral income, but recent declines in land and mineral prices have resulted in financial losses to ranch operations (Bowe 1987).

Cash shortfalls imply an inability to sustain the necessary long-term improvement needed in a livestock operation. Recent indications show that range improvements have not been and are not being put in place (Gilliam 1984, Lewis and Engle 1982). The projected supply scenario from Chapter 4 assumes an annual increase in forage productivity of only 0.7%. The historical volatility in livestock production costs will affect the ability of ranch/farm operators to implement technology necessary

[18]*Source: Terry Crawford, unpublished data obtained from the USDA Economic Research Service cost of production survey.*

for long-term improvements in forage production. In the past, a diversity of incomes from rangeland was important to maintain cash flow and long-term improvements. The imperative to be efficient and to diversify in order to remain in the industry was seen in the early 1980s (Special Advisory Committee 1982) and this appraisal is likely to reflect successful management strategies for the future as well.

Recent diversifications in ranching have included bed and breakfast operations (Wyoming Farm Bureau 1987), recreational opportunities such as cross-country skiing (Freese and Coble 1988) and hunter lease agreements (White 1987); harvesting the seed or the plants of native species (Goodin and Northington 1985, Proulx 1984), tree nuts, wood chips or fuelwood; alternative meat products such as buffalo, and livestock products emphasizing nutritional quality or production without chemicals (Briney 1987, Cohn 1987, Zuckerman 1987). The economic value of the range resource will reflect these outputs. Although less than 1% of private grazing land is currently used primarily for wildlife or recreational activities (Heimlich and Langer 1988), land owners who charge access fees for recreation or hunting are more likely to implement range improvement practices (Lacey et al. 1988).

ENVIRONMENTAL IMPLICATIONS

Environmental Implications Defined

Environmental implications involve an assessment of the ability of the land to sustain long-term productivity of range vegetation. Capital, labor, and state-of-the-art technology influence the productive capacity of forest and rangelands.

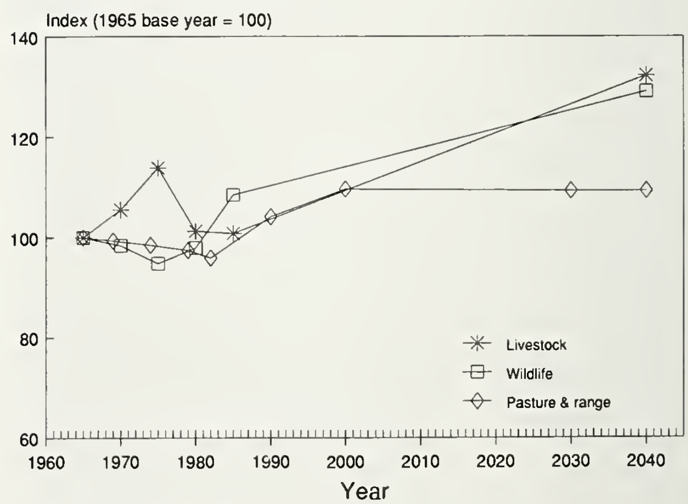
Environmental Implications of the Projections

The demand for meat, and consequently forage, are projected to be great enough to foster the implementation of technologies to sustain and enhance range productivity. Analyses explicitly linking the environmental and production processes and income objectives for either forage production or livestock production at the national level have not been developed. Economic theory would suggest that a strong demand for a product would strengthen the market for that product. The future scenario assumes an improved livestock market, and the consequent implementation of additional technologies to improve forage production. This future demand implies that management on rangelands will intensify.

The national projections for the supply and demand of range forage for livestock considered the potential impact of land use changes but these projections were made in isolation of the future supply/demand of other outputs, such as timber or wildlife. Multiresource interactions were examined in the regional case study discussed in Chapter 2 and for NFS lands at the national level by Hof and Baltic (1988). Those scenarios indicated an interaction between the production of timber, the production of forage, and to a greater degree, the production of wildlife.

Forest and rangeland supply food and habitat for both wildlife and livestock. A comparison of the projections for livestock grazing (from the present assessment) and wildlife grazing (from the Wildlife Assessment, Flather and Hoekstra in press) indicate a potential conflict (fig. 54). Big game numbers (elk, deer, and antelope) are projected to increase 19% by 2040 over 1985 inventories in the western United States. Livestock numbers are projected to increase 32% over the same period. Rangeland area is projected to increase only 5% by 2040 (fig. 54). The enhanced rangeland productivity is projected to meet only the increased forage demand for livestock. Even though domestic and wild grazers and browsers are often complementary users of rangeland and, thus, competition is not 100% temporally and spatially, grazing pressure from wildlife and livestock will increase in the future, beyond the projected supply. This intensive use of our Nation's ecosystems implies little likelihood that the condition of the vegetation or the productivity of the system will improve unless sufficient technology is implemented to enhance the productivity of these ecosystems.

Although enhancing rangeland productivity for livestock may increase the food and habitat for wildlife, some management intensifications for livestock may not necessarily improve the future wildlife situation. For example, the paddock cell layout associated with short duration grazing systems increases both human and domestic animal activity near the center of the cell where the water tank is often located. Some indications exist that wildlife avoid these highly congested areas, thus restricting wildlife access to water (Prasad and Guthery



NOTE.--12 of 15 western states reported.

Source: USDA (various years); Flather and Hoekstra [In press]

Figure 54.—Trends in livestock and wildlife AUMs and rangeland area in the western United States over historical (1965-1985) and projected periods (2000-2040).

1986). Even if the projected rising forage production were available to wildlife, this increase would not appear sufficient to meet demands from both domestic and wildlife grazing.

Obstacles and opportunities exist for allocating the grazing resource on rangelands. Economics and increasing regulation of agrochemicals have restricted the use of some improvement techniques. Previous overgrazing has left some range managers with degraded rangeland ecosystems. The U.S. Congress, Office of Technology Assessment (1981) reported that on some particularly fragile lands there are no currently available ways to sustain high levels of production. On other lands, technologies to enhance productivity are often not applied because users are not convinced the new technology will be profitable, innovative technologies require more management, and capital investment is greater than users can afford (U.S. Congress, Office of Technology Assessment 1981). The use of rangelands can be enhanced, however, with multiple species grazing (Baker and Jones 1985). These technological enhancements require the broadening of forage management and wildlife management into vegetation management.

Table 32.—Range forage prices (dollars per head per month) as determined by grazing fees on National Forest System lands and by market value appraisals.

National Forest System Region[1]	Grazing fee[2]	Market clearing price[3]
1	1.35	5.64
2	1.35	6.34
3	1.35	4.73
4	1.35	4.12
5	1.35	4.53
6	1.35	4.36
8	0.65	3.33
9	2.53	3.33

[1]*Assessment regions correspond to the following National Forest System regions: Northern Rocky Mountains, 1, 2, 4; Southwest, 3; California, 5; Pacific North, 6; Northern, 9; Southern, 8.*

[2]*See USDA Forest Service, and USDI Bureau of Land Management (1986), for grazing fee formula. Regions 8 and 9 prices were derived from equivalent hay price. Prices are based on dollars per head per month as used in grazing fee bills for collection.*

[3]*Market Value Appraisal, 1983, USDA Forest Service, updated to 1987. Regions 8-9 prices derived from hay prices.*

Source: Frandsen (1988).

DETERMINANTS OF VALUE

Range Forage For Livestock Production

The value of range forage grazed by livestock is derived from the value of the livestock produced. Thus, the value of range forage is a function of the values of the livestock, the value of other types of feeds and forage that might be used, and the efficiency of the livestock operation (Bartlett 1986). On NFS lands and BLM-administered lands, range forage is allocated by public policy. Thus, the value of range forage is not determined within a market system. In the past, the determinants of value within the fee system have included beef cattle prices, prices paid index, and the private grazing land lease rates (USDA Forest Service and USDI Bureau of Land Management 1986). A comparison of the 1987 public grazing fees and estimates of the market clearing price of forage by regions are shown in table 32.

An important consideration for resource decision-making is the current value of range grazing for livestock and any changes in that value in the future. The value of range forage over time should reflect changes in the factors that affect the use of range forage. These factors include outputs produced from forage, i.e., beef cattle or sheep, and changes in the production of other types of feeds that could be used as substitutes. Thus, trends in the value of private range forage might reflect historical trends in the available market transactions for forage, such as private grazingland lease rates. The valuation of private grazingland lease rates includes a multiplicity of factors, among which are services and facilities provided with the lease. As any historical shifts in these additional factors are difficult to examine, caution must be exercised in evaluating the trends in market prices associated with private land lease rates. In addition, the value of deeded private range may include values not measured in the private grazing land lease rates, such as the option to use the deeded land with greater flexibility than leased grazing land.

As the projection period for the assessment is 50 years, two historical series will be examined to assess trends in range forage values: the recent historical trend (1968-86) and the long-term historical trend (1870-1970). The trends in the recent historical past are most likely to influence the next 10 years whereas the longer historical series are most likely to influence the future long-term trend. The price in constant dollars (net of inflation) will be used to determine trends in the value of the range resource for livestock grazing.

The recent historical trends in the determinants associated with livestock grazing are given in table 33. The high inflation rates of the 1970s are seen in the difference between the nominal prices and the real (constant) prices. Although all nominal values increase over 1968-85, constant dollars remain nearly steady or decline for beef cattle, private grazing land lease rates, and wool prices. The cyclical nature of livestock production is also apparent in the cyclical pattern of the beef cattle prices.

The recent historical trends in the private grazing land lease rates (constant dollars) indicate a slight decline of 1% annually during 1966-86 (fig. 55). Private grazing land lease rates include various services other than the use of the range forage. This trend also reflects any changes in services other than forage provided, as well as a potential change in the value of the private grazing land lease rate.

Trends in hay prices (constant dollars) during 1968-85 have moved upward about 0.7% annually (fig. 56). Greater volatility is seen in this series when compared with the private grazing land lease rates (fig. 55).

Table 33.—Hay prices (dollars/ton), livestock prices (dollars/CWT), private grazing land lease rates (PGLLR) (dollars), and wool prices (cents/lb) from 1968 to 1986.

Year	Hay		Beef cattle		PGLLR		Wool[1]	
	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real
1968	23.60	23.60	22.04	22.04	3.65	3.65	40.5	40.5
1969	24.70	23.40	27.00	25.57	3.82	3.62	41.8	39.6
1970	26.10	23.42	29.50	26.48	4.05	3.64	35.4	31.8
1971	28.10	23.86	29.50	25.05	4.06	3.41	19.6	16.6
1972	31.30	25.38	36.80	29.84	4.17	3.38	35.0	28.4
1973	41.60	31.68	43.00	32.75	4.57	3.48	82.7	63.0
1974	50.90	35.54	39.20	27.37	5.82	4.00	59.2	41.3
1975	52.10	33.12	35.20	22.38	5.75	3.66	44.8	28.5
1976	60.20	38.97	36.10	21.57	6.37	3.81	66.0	39.4
1977	53.70	30.08	36.00	20.17	7.06	3.95	72.0	40.3
1978	49.80	26.00	47.60	24.85	7.11	3.71	74.5	38.9
1979	59.60	28.59	64.90	31.13	7.53	3.51	86.3	41.4
1980	70.90	31.19	64.20	28.24	7.88	3.47	88.1	38.8
1981	67.30	26.99	59.10	23.70	8.83	3.54	94.4	37.9
1982	69.30	26.13	57.70	21.75	8.36	3.15	68.6	25.9
1983	75.80	27.50	56.40	20.45	8.85	3.21	61.2	22.2
1984	72.70	25.45	57.79	20.19	8.86	3.10	79.5	27.8
1985	69.10[2]	23.43[2]	53.70	18.16	8.40	2.84	63.3[2]	21.5[2]
1986	NA	NA	51.79	17.05	8.50	2.80	NA	NA

[1]*Prices do not include wool support price payments.*
[2]*Preliminary.*
Note: Real prices are reported in constant (1968) dollars and are net of inflation or deflation.
Source: Hay and wool, U.S. Department of Agriculture (1968-1985); beef cattle prices, PGLLR, USDA Forest Service, and USDI Bureau of Land Management (1986).

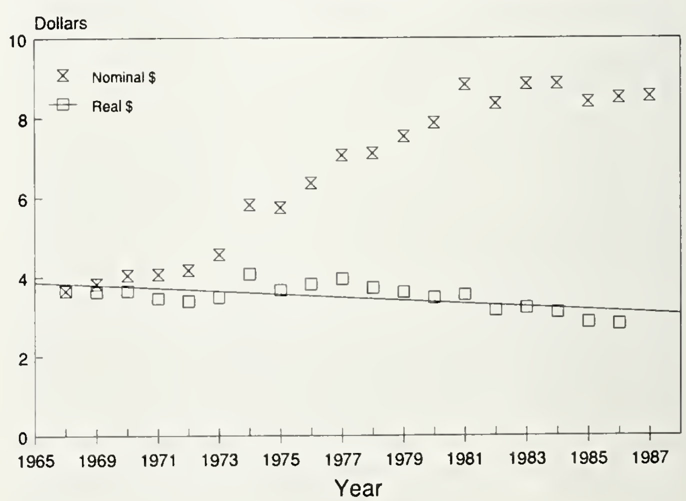
An examination of the determinants over a longer historical period indicates positive increases in all values, although fluctuation in prices associated with wool has been considerable (figs. 57 and 58). The annual increases in beef cattle prices and in sheep and lamb prices (constant dollars) over this 100 year period is nearly 1% (Manthy 1978). Wool, hay, and corn prices (constant dollars) show a greater fluctuation over this period but no clear trend is seen.

Range Vegetation

The determinants discussed above relate to the value of range forage in livestock production. The value of range vegetation is reflected in, but is not often measured by the value of grazing for wildlife, wild horses and burros, the habitat for threatened and endangered species, and the recreational experiences. The future value of range vegetation based on other output indicators might be different from the trends determined from forage for livestock. Increases associated with access hunting fees may reflect an attempt by the producer to find the market equilibrium price, but over the short-term indicate a substantial increase in value (fig. 51). Although not expressed in terms of monetary value, the increased number of threatened and endangered plant species suggest an increase in the value of rangelands as habitat for these species. As discussed earlier in this chapter, increased competition for the mix of resource outputs imply a continued and increasing social value for range vegetation management.

SUMMARY

The desirability of the projected future depends on society's social, economic, and environmental values concerning the range resource. Society's ideas about the range resource regulate preferences that function to influence the use of rangeland. Livestock enterprises and livestock grazing on rangeland will continue to contribute to the social well-being of rural communities. The increased demand for recreational experiences will



NOTE.--Real rates are reported in constant 1968 dollars.

Source: USDI, Forest Service and USDI, Bureau of Land Management (1986)

Figure 55.—Private grazing land lease rate.

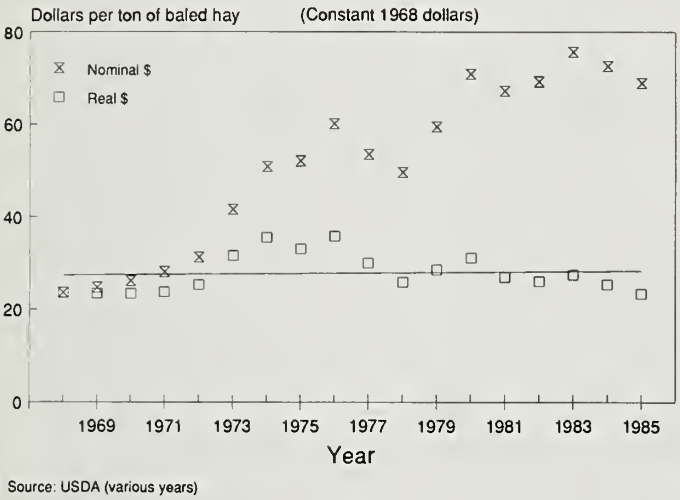


Figure 56.—Hay price per ton received by farmers, 1968-1985.

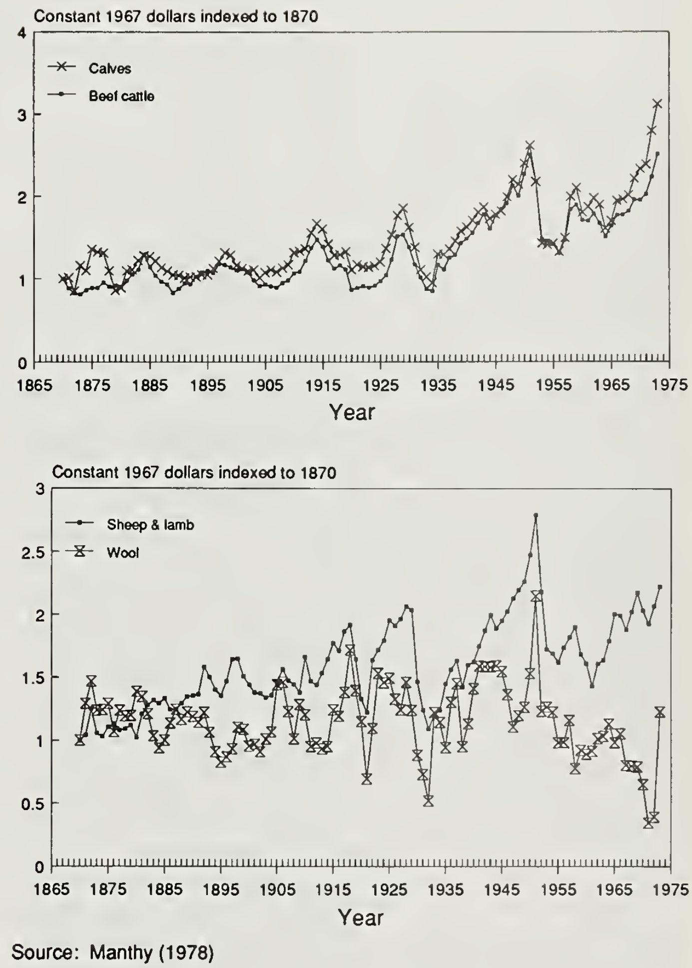


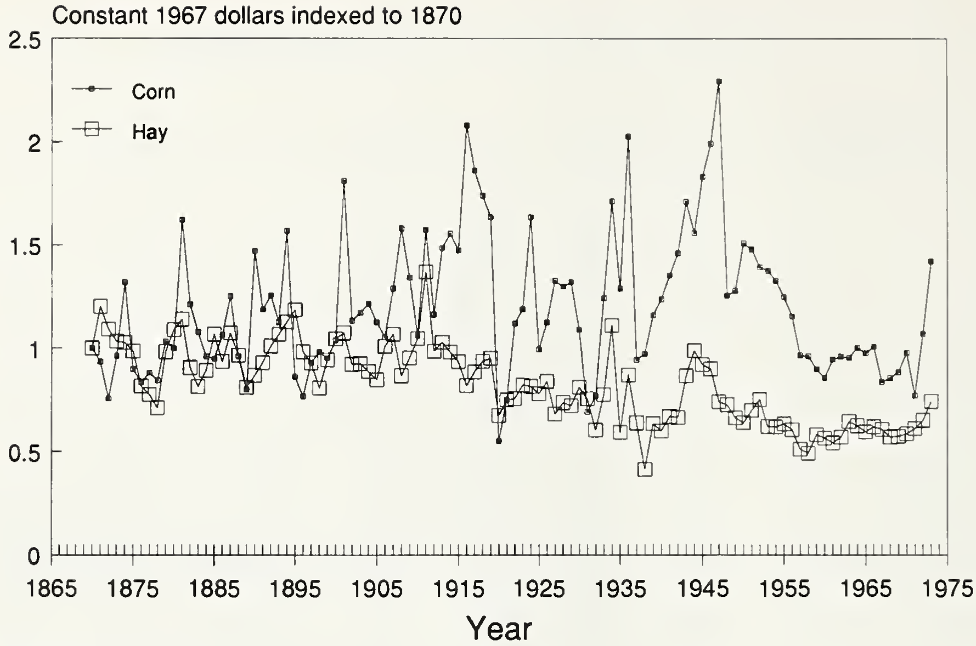
Figure 57.—A 100-year historical trend of prices received: livestock and wool.

increase the interaction between ranching operations and urban dwellers. Concern for rangeland health will be heightened in the future as demands for wildlife habitat, wild horse and burro habitat, and habitat for threatened and endangered plants and animals are increasing along with livestock production on forest and rangelands.

Although the projected supply of forage appears adequate to meet the projected demand for livestock grazing, the distribution of grazed forages will likely vary from historical patterns. In light of the overall increase in forage demand, a decline in relative shares of public grazing and irrigated pasture suggests that livestock operations unable to buy, grow, or otherwise obtain forage for all seasons to replace public forage or irrigated pasture will not be part of the future growth in this industry. Thus, fewer livestock operations will be associated with public lands, with a potential decline in service industries associated with livestock production in these rural communities. This decline, however, is tied to social pressure to remove livestock from public lands, which is related to an increased demand for recreation and wildlife outputs. Services associated with recreation will likely increase in these rural communities.

The enhanced rangeland productivity is projected to meet only the increased forage demand for livestock. Although domestic and wild grazers and browsers are often complementary users of rangeland and, thus, competition is not 100% temporally and spatially, grazing pressure from wildlife and livestock will increase in the future.

Recent historical trends in the values of private grazing land lease rates, prices for beef cattle and wool indicate a flat or declining trend. Trends over the period corresponding to the projection period of the assessment (50 years) indicate an increase of 1% in the prices of beef cattle, sheep and lamb. Wool, hay, and corn prices show a greater fluctuation over this period with no clear trend.



Source: Manthy (1978)

Figure 58.—A 100-year historical trend of prices received for corn and hay - indexed to 1870.

CHAPTER 6: ISSUES AND OPPORTUNITIES TO MANAGING THE RANGE RESOURCE

INTRODUCTION

The projections discussed in Chapters 4 and 5 identified future shifts in the forage production. Forage production on public lands and from irrigated pasture was projected to increase only slightly whereas the total demand for livestock forage was expected to rise. The relative declines in these sources of forage suggest that the management of alternative sources of forage, such as private lands, will intensify. Not only will this intensification involve livestock grazing, but also the need to diversify ranch/farm operations to stabilize income over the long term. Increasing demands for wildlife, recreation, and water production are also suggested (Flather and Hoekstra in press, Guldin in press). A future in which resource use intensifies, but management does not, poses the possibility that our Nation's ecosystems will not likely improve in condition or productivity. The management issues associated with the range resource are now broader than domestic livestock grazing. One important aspect of this national assessment is to review issues and opportunities that exist to potentially reduce these impacts and costs.

Management issues and opportunities are grouped into four categories: the *management of range vegetation; management of grazers and browsers*, both wild and domestic; *social* issues; and *planning*. Reports from National Forest System (NFS) range, wildlife, and fish managers, Bureau of Land Management (BLM) wildlife and fish managers, and state wildlife and fish managers were reviewed for perceptions of current management issues, opportunities that exist to address these issues, and obstacles to resolving these issues. In addition, published reports by special interest groups, professional organizations, producer groups, and universities were reviewed.

RANGE VEGETATION MANAGEMENT

Vegetation management issues revolved around providing the type of vegetation on public and private lands necessary for the production of a mix of resource outputs including forage for domestic and wild herbivores, water quality and quantity, air quality, open space, endangered plants and animals, genetic material, recreational use, plant diversity, community stability, scenic quality, and minerals (Cordell in press, Flather and Hoekstra in press, Guldin in press, USDA Forest Service 1988b, USDA Forest Service RPA Staff in press). Management issues of particular concern included the seasonal and spatial availability of forages for both wild and domestic herbivores, healthy riparian vegetation, and the control of undesirable plants.

Availability of Forage for Wild and Domestic Herbivores

Issues

An adequate supply of year-round forage for wild and domestic herbivores, the exceeded life-time of existing range improvement practices, natural successional changes reducing habitat or forage availability, and human activities reducing habitat and forage availability were seen as limiting factors in the management of wild and domestic herbivores (Flather and Hoekstra in press, USDA Forest Service 1988b, USDA Soil Conservation Service 1987c, U.S. General Accounting Office 1988). The projected declines in the regional availability of public forage and irrigated pastures (Chapter 4) will intensify the increasing demands for alternative sources of forage.

Plant production is greatest during periods of adequate moisture and optimal temperature. Outside of their optimal growth periods, grasses, forbs, and shrubs may grow little, if at all. During these periods, accessibility to alternative sources of forage is critical for wild and domestic grazers. Poor vegetative conditions in crucial winter range is a management issue for big game (Flather and Hoekstra in press). Inadequate forage production in cool-season pastures during the summer months is a concern in the Northern region (USDA Forest Service 1988b, USDA Soil Conservation Service 1987b). Summer range for pronghorn in the Rocky Mountain region is poor because of a lack of forbs that remain green during July and August (Flather and Hoekstra in press). Alternative nutritional sources of forage during the winter in the Southern region are needed for domestic grazers.

The expired lifetime utility of many range improvement practices and the need to broaden the types of practices implemented were concerns for most range managers (USDA Forest Service 1988b). Range plant control treatments are designed to temporarily shift plant succession (Young 1983). Many of these improvement practices were implemented several years ago and succession has resulted in the need to again treat these sites to maintain the present grazing strategy. On public lands, the lack of range funds and declining budgets have restricted the implementation of improvement practices (fig. 52). In 1985, the Forest Service had 561 range conservationists and technicians overseeing 9,000 grazing allotments within 103 million acres. Thus on average, each person oversees 16 grazing allotments covering 184,000 acres (U.S. General Accounting Office 1988). Declining range improvement funds has restricted improvement practices on BLM-administered lands also. A current vegetation analysis is needed before

developing range management objectives for NFS lands. Range managers were concerned that lack of funds and personnel would restrict the development of ecological guidelines for conducting these vegetation analyses (USDA Forest Service 1988b). On private lands, the economic incentive to implement range improvement practices has weakened (Chapter 3). This economically-driven delay in range improvement on public and private lands is intensified because the original practices such as chemical spraying or fire are no longer acceptable, and suitable economic alternatives may not exist.

The need to broaden the types of practices implemented on pasture/rangeland is the result of traditional attitudes limiting improvement practices, in addition to environmental restrictions on previously used treatments, such as herbicides. Traditional attitudes concerning range management limit the approaches that can be taken on forest and rangelands. The spacing of tree plantings at similar densities in southern timber plantations can inhibit forage production (evenly spaced) or enhance forage production (unevenly spaced across the field). Often, fertilization and liming were the only management practices considered in the Northern region (USDA Forest Service 1988b). The benefits of converting to cool-season grasses and of delaying livestock grazing were often not obvious to land managers. In a survey by the National Association of Conservation Districts, ranchers and farmers believed that the education of land operators was essential to achieve the application of proven range management practices (National Association of Conservation Districts 1979).

Succession affects continual changes in the vegetation structure on forest and rangelands (fig. 22). Abandonment of cropland and pastures, particularly in eastern United States, has resulted in declining acreages of open nonforested habitat, as the plant community moves toward the potential natural community. This displaces some wildlife species, represents a forage loss for wild and domestic herbivores, and also results in a loss of scenic vistas (Flather and Hoekstra in press). In some ecosystems, past use has been so intensive as to shift the ecosystem response to management (Chapter 2). Conversion to return the original vegetation type is an expensive process.

The USDA Soil Conservation Service (1987c) reported that nationally nearly 117 million acres of rangeland require intensive treatment such as brush management, range seeding, or erosion control. Brush treatment was recommended for sites where these invading woody plants were not part of the climax plant community or where these plants have expanded to densities much greater than the natural community. Not only does the encroachment of shrubs reduce forage, but water runoff may be higher, accelerating soil erosion (USDA Soil Conservation Service 1987c).

Opportunities

Management opportunities for range vegetation management exist in previously developed but not yet implemented technology, and in developing technology. The seasonal availability of forage can be improved by interseeding of a mixture of species within a pasture, converting part of the grazingland to other forage species, or adjusting the mix of animal species. Seeding warm-season grasses in cool-season pastures extends the period of available forage in the Northern region and in the plains area of the Northern Rocky Mountain region. On-going research at federal and state agricultural experiment stations is accelerating the interest in and use of warm-season grasses (USDA Soil Conservation Service 1987b). Techniques have been developed to process native grass seeds so that conventional grass drills can be used, and the availability of drills capable of seeding native seed is also increasing (USDA Soil Conservation Service 1987b).

Subterranean clover is a cool-season forage legume that may potentially improve winter nutrition for herbivores, and indirectly small game, on forested rangelands in the South (Johnson et al. 1986, Ribbeck et al. 1987). This species would grow most during the winter when other forage is of poor nutritional quality. This clover is also a major spring forage on the western coast of the Pacific Coast region. The only disadvantage is that it requires intensive grazing and management to be productive. Opportunities to interseed arid rangelands with adapted forbs were seen as possible methods to extend summer range use for pronghorns. On big game winter range, a reduction of domestic grazing could provide additional forage.

Within a mosaic of land ownerships, changing land uses place increasing importance on the vegetation management on lands available for grazing. Development around public lands such as ski developments or second homes, or the encroachment of urban lands into the rural areas creates barriers to migratory wildlife routes and limits access for livestock grazing. Coordinated management opportunities exist to mitigate problems associated with changing land uses or intermixes of land uses. Opportunities to exchange lands to block up crucial winter ranges in public ownership were seen as possibilities to address the seasonal shortage of forage for big game. Opportunities to mitigate the habitat loss of wildlife species also includes the outright purchase of lands by federal, state, or private groups (Flather and Hoekstra in press).

Research Needs

The lack of ecological knowledge in vegetation management and the need for technology transfer from researchers to managers were seen as issues in vegetation management research. A comprehensive understanding of the regulatory mechanisms of plant growth and how it responds to environmental extremes are objectives for further research (Society for Range Management 1989). Existing models used in resource management to forecast future plant communities and resource outputs have not been tested in different ecosystems or under different successional stages, and

the underlying ecological assumptions in these models need further examination (Sweeney and Wolters 1986). Additional study is needed to determine the impact of grazing systems on vegetation productivity (USDA Soil Conservation Service 1987b). Sustainable management systems to integrate land uses are needed to manage vegetation and other components of the ecosystem (see Planning section of this chapter).

Healthy Riparian Vegetation

Issues

Many western public resource managers believe that conflict arising over the management of riparian zones is, except for timber management, the most potentially explosive issue of today (Prouty 1987). The 1986 Audubon Wildlife Report identified damage to riparian zones by cattle grazing on public lands as the most serious current conflict between wildlife and livestock (Barton and Fosburgh 1986). Over 90,000 miles of streams and rivers providing nearly 3 million acres of riparian habitat are administered by the NFS and BLM (Prouty 1987). Riparian areas are attractive to recreationists for many reasons including presence of water, easy access, fishing opportunities, and esthetically appealing landscape (Johnson and Carothers 1982, Melton et al. 1984, Skovlin 1984). The stability and integrity of streambanks, and adequate shade and overhanging cover are important in maintaining healthy fish populations (Cummins 1974, Moring et al. 1985).

Riparian zones contain higher density and diversity of plant and animal species than adjacent uplands (Odum 1979). Livestock and wildlife use riparian areas disproportionately more often than upland habitats (Kauffman and Krueger 1984, Marlow and Pogacnik 1986). In Oregon, a riparian zone comprising less than 2% of the total land area produced 21% of the available forage and accounted for 81% of the total herbaceous vegetation removed by livestock (Roath and Krueger 1982). Of the 166 bird species nesting in southwestern United States, 127 (77%) were dependent on water-related habitat (Johnson et al. 1977). Forty percent of the vertebrate wildlife species in Colorado are associated with riparian areas that occupy 3% of the land area (Melton et al. 1984). Riparian zones also serve as migration corridors for wildlife, especially big game traveling between summer and winter ranges (Melton et al. 1984, Thomas et al. 1979). With all of these demands, riparian ecosystems are the most critical area for multiple-use planning (Platts 1979).

Opportunities

Proper vegetation management of riparian zones can produce a variety of resource outputs, including fisheries, wildlife, recreation, livestock, and water quantity and quality. Wildlife that utilize riparian areas include big game such as deer and elk, small game, nongame, and furbearers. Riparian area management presents the biggest challenge and opportunity for multiresource planning and cooperation. Western rangeland streams are in their present condition because 100 years of small, annual degrading effects were cumulative over time. Land managers must administer grazing strategies with finesse to meet today's needs while attempting to correct the mistakes of the past (Platts and Raleigh 1984).

Based on early research on riparian zones, many allotments on NFS lands receive less overall livestock use and have been changed from season-long grazing to other grazing systems. Rest-rotation grazing has been effective in rehabilitating riparian areas that are non-woody or have established woody stands (Platts and Nelson 1985a). In critical fish habitat, grazing has been eliminated by fencing some stream sections to protect spawning habitat of anadromous fish. The special management pasture offers an expensive, but flexible management practice to continue grazing under more focused management (Platts and Nelson 1985b). Different livestock species graze riparian areas in different ways. Sheep, which graze riparian areas without extensive damage, are no longer present on many allotments (Platts and Raleigh 1984).

Fishery biologists are attempting to improve degraded stream sections through instream structures designed to catch sediment and through planting willows and other shrubs to stabilize streambanks (Malespin 1985, McCluskey et al. 1983, Storch 1979). Channel structures that deposit sediment enhance riparian development by providing more favorable moisture and nutrient regimes and a reduction in flow velocity (DeBano and Heede 1987). Willow planting provides habitat for many wildlife species in a short amount of time at a low cost (McCluskey et al. 1983).

Research Needs

Much has been learned in the past 20 years about the structure and function of riparian zones, but this complex ecosystem is still not fully understood. Recent and present research is concentrating on entire riparian ecosystems and watersheds (Platts 1986). Grazing strategies are being matched to the physical conditions of the grazing area (Platts and Raleigh 1984). Researchers are focusing on how riparian areas function, and studies are underway on how to get degraded streams to function properly again. The BLM in Oregon is learning how to manage mud or sediment by examining the basic stream processes and maintaining vegetative cover during peak runoff (Elmore 1988, McKinney 1988). Nutrient cycling within and through riparian areas is being studied (Warwick and Hill 1988). Changes in the microbial aspects of riparian zones may provide an early warning to unwanted successional change (Hussey et al. 1985). Scientists are also looking at the impacts of natural disturbances such as flood events and how the stream changes with these disturbances (Platts et al. 1985). Inventory techniques are being modified and refined to better judge the condition of riparian areas (Platts et al.

1987). Platts (1986) stated that research leading to successful rehabilitation of riparian areas is in its infancy and should receive the highest priority in the future.

Little information is available on the riparian habitat requirements of threatened and endangered species or invertebrates (Patton 1977, Skovlin 1984). Few studies identify how present cattle grazing strategies will restore riparian habitats (Platts and Raleigh 1984). Range managers need more information on the costs and benefits associated with different livestock management strategies. The impacts of multispecies grazing in riparian areas needs to be explored both biologically and economically. Long-term hydrologic impacts of livestock grazing need to be addressed (Blackburn 1984).

Knowledge gaps exist between fishery and wildlife biologists, and range managers (Skovlin 1984). Range, wildlife, and fishery scientists base management decisions on functional sets of criteria, such as meat production, wildlife population size, or quantity and kinds of fish (Platts and Raleigh 1984). Platts and Raleigh (1984) did not find a single published interdisciplinary grazing study in their literature review. They stated that a compelling need exists for studies that identify common goals and incorporate the concerns of all users, including ranchers, fishermen, hunters, ecologists, and recreationists.

Undesirable Plants

Issues

The spread of undesirable plants is a particular concern among resource managers (Flather and Hoekstra in press, USDA Forest Service 1988b). An undesirable plant is one that is unacceptable in light of planned land use or that is unwholesome to rangelands or range animals (Vallentine 1980).[19] These plants can be exotics that spread into the native community or native species whose dominance is undesirable. Acceptance of a plant species depends on what plant species, and how, when, where, and for what is it desirable (Vallentine 1980). Plants undesirable for one grazing animal may be valuable for other herbivores, as habitat for wildlife, or valuable to other industries such as beekeeping. For example, tall larkspur is poisonous to cattle, but is palatable, nutritious forage for deer and sheep (Vallentine 1980). The introduction and persistence of nonnative plants and animals is jeopardizing the habitat of native plants and animals including some threatened and endangered species (Chapter 2).

Species and rates of infestation differ across the United States. Diffuse and spotted knapweeds reduce forage production, decrease range carrying capacity, have high fibre content, and form solid stands with their competitive advantage of allelopathy (Maddox 1982). These two species have infested over 3.5 million acres in Oregon, Washington, Idaho, and Montana. Maddox (1979) estimated that the economic loss to cattle operations in 750,000 acres of knapweed-infested range is $600,000 annually. Grazing capacity on elk-bighorn-deer winter range has been reduced 35% to 80% from knapweed invasion in western Montana (Mass 1985). Leafy spurge can lower range carrying capacity by 50% to 75% (Maddox 1979). This loss is the result of decreased forage production from leafy spurge competition, and decreased forage availability because cattle will not graze areas heavily infested with spurge (Lym and Kirby 1987). The current infestation level is estimated at 2.5 million acres in North America (Lacey et al. 1985). Annually, $6 million is spent for spurge control and over $7 million in forage and beef production is lost from decreased forage production on spurge-infested rangelands in North Dakota (Lacey et al. 1985). Infestations of yellow starthistle have been reported in 23 of the 48 conterminous states; over 7.4 million acres are infested in California alone (Maddox et al. 1985). Although this plant has a negative impact on grazingland, grain and seed crops, and is toxic to horses, yellow starthistle is a valuable honey plant for the maintenance of bee colonies in California (Maddox et al. 1985).

Introduction and spread of exotic species has been facilitated by impurity in crop seed, adhesion to animals, soil surrounding roots of nursery stock, and the deliberate introductions of plants as forage, fiber, medicinal, ornamental, erosion control, and timber stock (Baker 1986). The spread of native species can be associated with natural succession, climatic fluctuations favoring these species, and local denudation such as road right-of-ways, stock trails, off-road vehicle use, or heavy grazing by livestock. Within a geographic area, native and exotic plants can spread along transportation corridors (railroads, highways, stock or recreation trails), and can spread by cultural practices such as cropping. The activity that most ensures a successful plant invasion is disturbance caused by human activities (Baker 1986, Mass 1985). Because the spread of undesirable species is oblivious of ownership, the problem is a multi-agency one. Lack of funding, research, technology transfer, awareness, and integrated control programs are allowing a significant increase in undesirable plant species.

The reliance of past management on chemical control has resulted in a related management concern, the loss of pesticides. Environmental legislation has increasingly focused on the dispersal of toxic substances in the environment (table 34). Previously used chemicals are being withdrawn from public and private use because of environmental concerns. This restriction places a greater importance on the development and implementation of environmentally safe control methods.

The implementation of any control method requires the consideration of costs and benefits. Fire has been the least expensive method for controlling undesirable vegetation (Stoddart et al. 1975). Poor economic conditions within the ranch/farm sector have resulted in a sharp drop in pesticide production in recent years. Surveys in North Dakota indicate that about 50% of the total combined acreage including cropland, alfalfa, hay, rangeland, and summer fallow was not treated with any pesticide in 1984 (Agrichemical Age 1986).

[19]*Federal and state laws define certain plants as noxious weeds because they are especially undesirable, troublesome, and difficult to control.*

Table 34.—Pollution control statutes in the United States.

Year passed	Statute
1970	Resource Recovery Act (amendments to the Solid Waste Disposal Act)
1972	Water Pollution Control Act Amendments
1972	Federal Environmental Pesticide Control Act (Amendments to the Federal Insecticide, Fungicide and Rodenticide Act)
1974	Safe Drinking Water Act (Amendments to the Public Health Service Act)
1976	Resource Conservation and Recovery Act (Amendments to the Resource Recovery Act focusing on hazardous wastes)
1976	Toxic Substances Control Act
1977	Clean Water Act (Amendments to the Water Pollution Control Act)
1978	Federal Insecticide, Fungicide and Rodenticide Act Amendments
1980	Comprehensive Environmental Response, Compensation, and Liability Act (commonly referred to as the Superfund)

Opportunities

The intensified public awareness of herbicide use on rangeland, coupled with increasingly sophisticated application techniques and increased knowledge of herbicide chemistry, has provided the incentive for research on the fate of herbicides in the ecosystem and for alternative control methods such as biological control. Present research on chemical control of undesirable plants has focused on short-lived chemicals that are highly toxic when first applied, are used in smaller quantities per unit area, and break down rapidly (Conservation Foundation 1984).

Increased interest in biological control agents is the result of several factors including the marginal economics of rangeland, the increased cost of petroleum-derived chemicals, the development of resistance in some weeds to herbicides, the inaccessibility of rangeland to herbicide application, and the restrictions on herbicide use along waterways and on public land (Nowierski 1984). Worldwide, 57 attempts to partially or completely control plants biologically have been successful and one of the startling successes was the control of St. Johnswort in California (Dahlsten 1986). Agents examined for use in biological control include insects, pathogens, and grazing animals (table 35). Biological control agents offer a number of management opportunities for rangelands: (1) the application on economically marginal land where expense or difficult terrain excludes the use of herbicides or cultural management, (2) permanency where the established control agents reappear annually to impact the undesired plant, (3) environmental safety with no toxic residues, (4) specificity where only the undesired species is attacked, (5) cost-effectiveness, and (6) the potential integration of biological control with chemical and cultural management strategies (Nowierski 1984). Unlike chemical or mechanical efforts that attack the plant for short-term success, biological control methods take longer to get established, the populations must build up, and the kill extends over a longer period of time as the host and control agent equilibrate. Presently many biological agents are under study, but only a few have been successfully released. Animals, such as sheep and goats, will graze plants such as leafy spurge (Fay and McElligott 1987, Landgraf et al. 1984) and can be an economically efficient method for control (Lacey et al. 1984). Proper management is needed to avoid any toxicity response to leafy spurge by sheep.

Opportunities exist to increase the public and private manager's awareness of undesirable plants through a coordinated state effort. Multiresource funding on public lands would give the range manager the funding and support to inventory, control, and monitor undesirable plants. Increasing the awareness of undesirable plants becomes important as interest in xeriscaping (landscaping with drought-hardy plants) offers another method for plant dispersal across the western United States.

Research Needs

The ecology of undesirable plant species is little known. The physiology and ecology of undesirable plants is an important step in developing environmentally sound control methods (Society for Range Management 1989). The mathematical modeling of invasion by colonizing plants has not been extensively developed but offers much promise in understanding the biology of these species (Bazzaz 1986). The ease of establishment and spread of knapweeds, the role of range condition in determining invasion rates of leafy spurge, and the unknown role of livestock grazing in the control of several undesirable plants were knowledge gaps identified for the western United States (Leininger 1988).

Although methods of chemical control may be available for a variety of undesirable plants, biological treatment is more likely only under study at present (table 35). Biological control appears to offer numerous advantages to control pests on rangelands, but several disadvantages exist. Biological agents are necessarily subjected to an exhaustive series of tests to guarantee their safety. Although geographically separate, leafy spurge, Canada thistle, and Tansy ragwort have plant relatives that are threatened or endangered plant species (table 35, Appendix C). Biological control methods must be

Table 35.—Some plant species of special concern on pasture and rangelands and their control treatments.

Species	Common Name	Treatment		Biological treatment			
		Chemical[1]	Mechanical	Insects	Pathogens	Grazing[2]	Plants[3]
Introduced							
Bromus tectorum	Cheatgrass	Yes	Yes			C	
Cardaria draba	Hoary Cress	Yes		Study[4]	Study		
Carduus acanthoides	Plumeless thistle	Yes		Study	Study		
C. nutans	Musk thistle	Yes	Yes	Study	Study		Yes
C. pycnocephalus	Italian thistle				Study		
C. tenuiflorus	Slenderflower thistle				Study		
Centaurea calcitrapa	Purple starthistle	Yes					
C. diffusa	Diffuse knapweed	Yes	Yes	Study	Study	S	
C. maculosa	Spotted knapweed	Yes	Yes	Study	Study	S,C	
C. repens	Russian knapweed	Yes	No	Study	Study	S	
C. solstitialis	Yellow starthistle	Yes		Study			
Conium maculatum	Poison hemlock	Yes					
Cytisus scoparius	Scotch broom			Study			
C. monspessulanus	French broom			Study			
Halogeton glomeratus	Halogeton	Yes		Study		S,G	
Hypericum perforatum	St. Johnswort	Yes	Yes	Yes		S	
Isatis tinctoria	Dyers woad	Yes		Study			
Lepidium latifolium	Perenial peppergrass	Yes	Yes				
Linaria dalmatica	Dalmation toadflax	Yes		Study			
Salsola paulsenii	Barbwire Russian thistle						
S. iberica	Russian thistle			Study			
Senecio jacobaea	Tansy ragwort	Yes		Yes			
Sonchus arvensis	Perennial sowthistle						
Tamarix pentandra	Saltcedar	Yes	Study				
Ulex europaeus	Gorse			Study			
Euphorbia esula	Leafy spurge	Yes	Yes	Study	Study	G, S	Yes
Cirsium arvense	Canada thistle	Yes		Study	Study	Study	Yes
Native							
Delphinium spp.	Tall larkspur	Yes				D, S	
Gutierrezia sarothrae	Snakeweed	Yes		Study	Study		
Larrea tridentata	Creosotebush	Yes	Yes	Study			
Opuntia spp.	Prickly pear cactus	Yes	Yes	Yes			
Prosopis juliflora	Mesquite	Yes	Yes	Study	Study	C,G after burn	

[1]*Chemical treatment with yes indicates that there are chemicals on the market that have been used to treat this species. Species may require one or more chemical, mechanical, or biological treatments.*
[2]*G = Goats, S = Sheep, D = Deer, C = Cattle.*
[3]*Other plants can out compete this species.*
[4]*Research under way.*
Source: After Leininger (1988); U.S. Department of Agriculture, Agricultural Research Service (1984); USDA Forest Service, Intermountain Region (1986); Vallentine (1980).

specific enough to attack only one spurge in a genus with over 100 species. These conflicts of interest intensify the research required to develop a host-specific biological agent.

Current research efforts in the use of livestock for plant control appears to be small. Brock (1988) stressed that very little is known about the impact of short-term rotational-intensive grazing programs on less desirable forage. The combination of technology in weed, range, and animal sciences in a well-defined long-term research program is needed to assess the role of livestock grazing in integrated pest management programs for range (Brock 1988).

Early work on chemical control focused on the development of long-lasting compounds which would provide long-term protection and require fewer applications (Conservation Foundation 1984), however this research did not focus on the ultimate fate of herbicides in the environment (Scifres 1977). The most important research priority identified by members of the Weed Science Society of America was the need to develop new methods for controlling the movement of herbicides into ground water, surface water, and air (McWhorter and Barrentine 1988). Within this research area, specific research topics included the development of new application techniques that minimize or eliminate herbicides and their residues in air and water, and techniques that regulate the movement of herbicides through the soil profile to avoid contamination of groundwater.

MANAGEMENT OF GRAZERS AND BROWSERS

Management issues related to wild and domestic herbivores focused on the number and kind of animals, seasonal distribution of these animals, availability of

suitable grazers and browsers, and the management of large herbivores on public lands. Although the management of livestock on private and public lands has a long history, the management of wild browsers and grazers is a relatively recent phenomena (Flather and Hoekstra in press). Questions still remain as to the specific objectives of wildlife and fish management. Should wildlife and fish be maintained on islands of habitat or as part of the total landscape (Berryman 1983)? Managing wild grazers and browsers to be part of the landscape requires integrating the forage and browse needs of these animals within a multiple species grazing program on range and forest land.

Public land managers' concerns addressed the management of land, whereas state agencies were concerned with the conversion of forest or rangeland to uses not compatible with wildlife (Flather and Hoekstra in press, USDA Forest Service 1988b). The impact of herbivores on riparian vegetation, also a concern, was discussed in the vegetation management section above.

Multiple Species Grazing

Issues

Managing for the needs of livestock, wild herbivores, and other wildlife species were concerns raised by resource managers (Barton and Fosburgh 1986, Flather and Hoekstra in press, USDA Forest Service 1988b). Overgrazing by livestock, overutilization of riparian areas by herbivores, lack of suitable grazers, the lack of proper grazing systems, and the need to manage for both wild and domestic herbivores were among the concerns.

Within the Forest Service planning process, range managers were concerned that the development of allotment management plans (AMP) would be hindered by time/personnel/funding problems (USDA Forest Service 1988b). The development of the AMP is the site-specific planning process designed to meet the resource objectives in the Forest Plan. The standards and guidelines associated with the Forest Plan address the ecological management objectives for plant associations, utilization objectives, and riparian objectives. This need to develop or revise allotment management plans that meet the planning objectives on BLM lands was also raised as a management concern. Difficulties with permit administration and violations of the terms of the permit were also management issues on public lands.

The most important wildlife and fish management issue cited by BLM biologists was the effect of livestock grazing on wildlife habitat (Flather and Hoekstra in press). The deteriorated quality of big game winter range, small game habitats, and riparian communities, as well as threatened and endangered species were issues related to livestock grazing. Because the mandate to manage BLM-administered lands for multiple use is a recent direction, comprehensive information is lacking on the amount and status of wildlife and fish populations and their habitats, and the distribution of threatened and endangered species. This lack of information is inhibiting effective management on BLM-administered lands (Flather and Hoekstra in press).

The suitability and availability of grazers or browsers was another concern of resource managers. Certain lands, because of vegetation or terrain, are more suited to one type of grazer or browser, or to a mix of these animal types. The Rocky Mountain region has a large area of rangeland that is best suited for domestic sheep use, or because of vegetation management purposes, needs a change to browsing animal. This lack of suitable herbivores was also a problem for managing lands infested with certain undesirable plant species. Sheep and goats can graze range infested with woody species, but limited markets restrict the availability of these animals for grazing public lands and restrict an expansion of sheep enterprises within the private sector. Resource managers on BLM lands reported acres of suitable habitat for the desert bighorn, but no animals available to place in these areas.

About 136 million acres of nonfederal rangeland are well-managed, about 134 million acres could be improved by refinements in grazing management, and about 117 million acres need more intensive measures (USDA Soil Conservation Service 1987c). Controlling livestock numbers, and season and duration of grazing could improve the condition of 134 million acres of nonfederal rangeland. The desired vegetation is present on this rangeland, but plant vigor or stands could be improved by such practices as proper grazing use, deferred grazing, planned grazing systems, and fencing and water facilities for improved animal control and grazing distribution. The remaining 117 million acres would require more intensive treatment, such as brush management, range seeding, or erosion control (USDA Soil Conservation Service 1987c).

Economic pressures in the livestock industry have influenced the viability of many livestock enterprises. In 1986, 43% of the beef, hog, and sheep farm/ranch enterprises had negative net cash household incomes (Gee and Madsen 1988). Low livestock prices, high production costs, low land values, and little borrowing power may necessitate a diversification of multiple use within livestock enterprises (Grazing Lands Forum 1987). The Special Advisory Committee to the National Cattlemen's Association reported in 1982 that opportunities for profitable operations through 1990 will go largely to the better informed and more able planners and managers (National Cattlemen's Association 1982). This forecast will probably apply in the near future also.

Opportunities

Management opportunities to enhance the use of herbivores on forest and rangelands exist. For some situations, planning methods or organizational structure are present but limited by funding or personnel. The development of allotment management plans on public lands would facilitate the implementation of desired management objectives, but funding and personnel restrict the number of these plans that can be accomplished.

In other situations, the technology transfer to public and private management limits the optimal use of range and forest lands.

The management of multiple species of grazers and browsers could increase the efficient use of range and forest vegetation (Baker and Jones 1985). Multiple species grazing includes the grazing of one animal after another has already grazed the area, or the grazing of two of more species at the same time. Animal species could include domestic, wild, or animals of both types (Baker and Jones 1985, White 1987). The volatility in the cattle industry has sparked a recent interest in the profitability of wildlife within a ranching operation (Bedell and Rasker 1987, Rollins 1988).

As summarized by Baker and Jones (1985), the advantages of multispecies grazing systems for domestic animals include:

1. *Complimentarity*: Different animal species have different preferences for plant species, differential ability to digest various types of forage, and different patterns of forage harvesting (animal behavior).
2. *Improved pasturerange management and forage production*: Multispecies grazing enhances herbaceous production through increased species diversity and the maintenance of plants in vegetative states.
3. *Parasite management*: Alternating pastures between species helps to break the life cycles of parasites.
4. *Predator control*: Aggressive behavioral differences in grazing animals may help reduce predator losses.
5. *Diversification and income stability*: The risk associated with volatile market prices is spread over a number of outputs rather than a single product.

Multiple species grazing also carries some disadvantages: increased facility costs because of diverse species requirements, potential labor conflicts such as the coincidence of calving and lambing, need for increased management skills in the knowledge of species nutrition, diseases, parasites, breeding practices, marketing, and predator control (Baker and Jones 1985). Although the spread of disease is a concern in a multispecies grazing operation (Davis 1985), certain operations may reduce the likelihood of disease spreading from livestock to wild herbivores. For example, the only new animals annually introduced to a cow-calf operation are bulls which have been carefully chosen and inspected for disease, whereas in a stocker operation, many new animals, calves or yearlings, are bought and placed on the range each year (Cooperrider 1985).

Optimization in a multispecies operation results in an overall gain, rather than the maximization of a single species. Reduced numbers of each species in the operation might result in some loss in volume discounts on services and materials (Baker and Jones 1985). Multiple species management requires a careful evaluation of the range and forest land resource. Otherwise, this management may cause ecosystem deterioration when there is a critical habitat overlap of grazing animals, such as in riparian zones (Schuster 1985).

Research Needs

Resource managers and others associated with range recognize the need to broaden the research objectives for range. Range management must be based on ecological principles and defined in terms of species composition, ecological condition, and the ability to provide a specified sustained level of use. The need to understand the relations between plants, animals, and soil was one of seven research goals developed by the Society for Range Management. Research needs related to the grazing animal and better management systems included: (1) the impact of grazing animals on the morphology and physiology of pasture and range plants, (2) how plant characteristics such as palatability and nutrient value affect livestock behavior, distribution and performance, and (3) the response of grazing animals to micro- and macro-changes in plant communities (Society for Range Management 1989).

Information on the economics of range management, particularly different grazing systems, is a critical need (Society for Range Management 1989, USDA Soil Conservation Service 1987b). Management needs outlined by the Soil Conservation Service stressed the connection between ecological processes and the economics of management (USDA Soil Conservation Service 1987b). Landowner requests for SCS assistance to plan and implement grazing systems led to a recognition of limited information on the effects of grazing systems on soil compaction, infiltration, runoff, erosion, water yield and quality; on plant succession, seedling establishment, nutrient cycling, plant vigor, and plant populations; on appropriate stocking rates, animal performance, and livestock production; and on wildlife habitat response and populations (USDA Soil Conservation Service 1987b). Technology transfer needs of currently available research results were recognized by Society for Range Management (1989).

Livestock as a Vegetation Management Tool

Issues

Restrictions on the use of herbicides have resulted in steadily increasing populations of undesirable plant species. This problem occurs in timber plantations where plant control is desirable to reduce herbaceous and browse vegetation from competing with the planted trees. The problem with respect to herbivore grazing and habitat for threatened and endangered species on rangelands has been discussed in the section above on undesirable plants.

Opportunities

Different livestock species have different forage preferences and under proper management, these preferences can be used to modify the vegetation to meet resource objectives for timber, wildlife, or recreation. One of the

strategies recommended by the work group of the 1985 National Range Conference was to increase and enhance the opportunities to use livestock grazing to manipulate vegetation to meet land management objectives (Dunlop 1987). Livestock grazing has been used to reduce shrub growth which improves summer or winter range for wild or domestic grazers. The use of livestock as a vegetation management tool requires the presence of nutritional forage, consideration of the costs of control, and appropriate livestock for vegetation present. Proper grazing management should be timed to reduce the vigor of competing vegetation, maximize soil moisture and nutrients for desired species, and on tree plantations, to minimize browsing of tree seedlings and reduce trampling (Doescher et al. 1987, Sharrow and Leininger 1982). Sheep grazing reduces browse growth (Sharrow and Leininger 1982), and promotes herbaceous growth of grasses and forbs. On forested sites, this not only benefits the young trees but enhances the nutritional quality of the shrub regrowth for the benefit of the wildlife that return to the area once the sheep have been removed (Pearson 1983, Wray 1987).

Weyerhaeuser Company in southwest Oregon has implemented a grazing program on over 600,000 acres of forestland (Doescher et al. 1987). The Alsea District of the Siuslaw National Forest is testing the use of sheep in Douglas-fir plantations. Cattle grazing in southern pine plantations has also received much study (Pearson 1987). Because of the mixed vegetation and variable topography, ranchers on the Edwards Plateau in Texas have long recognized the value of grazing cattle, sheep, and goats on the same range. After mechanical brush treatment on the Grand Prairie in Texas, a grazing system of cattle was enhanced by Angora goats to consume the browse regrowth (Scifres 1980). Livestock grazing is being used in the Northern region of the United States to maintain openings for wildlife. In studies on the Fremont National Forest in Oregon and the Modoc National Forest in California, heavy early grazing by cattle reduced grass growth and enhanced shrub growth, indicating a potential tool to improve decadent bitterbrush on Great Basin deer winter ranges (Neal 1982). Grazing cattle and horses in Utah improved shrub habitat for wild herbivores also (Urness 1982).

Research Needs

Research needs for the use of livestock as vegetation management tools include better information on the type and kind of livestock capable of controlling different competing vegetation, such as browse under timber plantations and undesirable plants on rangelands (Society for Range Management 1989, USDA Forest Service 1988b). Range resource managers identified the need to define how a change in livestock type can manipulate the vegetation composition to improve other resource values, such as wildlife habitat (USDA Forest Service 1988b).

SOCIAL ENVIRONMENT

Issues

As the United States becomes increasingly urbanized, more people from urban areas will influence management in rural areas. Social issues raised by range managers included the public's perception about range and livestock and the current and future direction of the range profession.

Range resource managers stressed the importance of promoting, internally and externally, the perspective that range management is the science and art of managing range vegetation for multiple use outputs (USDA Forest Service 1987c). Unfortunately, many people perceive that range and range managers are only concerned with livestock. Busby (1987) criticized the Society for Range Management for narrowly directing its efforts only toward livestock use of rangelands. Resource managers stressed that livestock can serve as a management tool to modify vegetation on range and forest land as a replacement for chemical control, but this option is often not available because of public resistance to livestock grazing on public lands.

Animal rights and animal welfare issues were also concerns. Animal welfare concerns have fostered the development of newly formed animal care committees on many university campuses, the passage of the federal Dole/Brown Bill ("Improved Standards for Laboratory Animals Act"), revisions of the Public Health Service's animal care guidelines, and withdrawal of funding from institutions found in violation of animal care regulations (Schmidt 1987). Although these actions have focused on laboratory animals, animal welfare groups are also concerned about commercial meat and egg production (i.e., egg production using hens in battery cases, and veal production methods), and wildlife management (i.e., hunting and trapping).

Enrollment in natural resource programs has declined as a result of few entry-level jobs being available in the late 1970s. Undergraduate enrollment in wildlife programs in 1985 was 40% lower than the peak years of 1974-77 (Hodgdon 1987). Similarly, the 1985-86 enrollment in forestry technician programs was 40% of the 1977-78 enrollment (Martin and Jahnke 1987). Similar statistics for range programs were not available.

The issue of career advancement within the range profession concerned the upward mobility within an agency as well as the proper training for natural resource management work. Because career ladders do not exist for range conservationists within public agencies in some areas of the United States, it is difficult to find and keep competent people in range management.

Kennedy (1987), in examining career development of range conservationists in their first 3 years with the Forest Service, noted that working "out-of-doors" dominated the job motivations of these young professionals. University curriculums emphasize field methods, but, very few of the range conservationists surveyed spent over 50% of their time in the field; a significant proportion was spent in planning/administering and coordinating

between the Forest Service and their clients or other agencies (Kennedy 1987). Public involvement has become a significant part of natural resource management since the environmental legislation of the 1970s.

Opportunities

The need for increased communication between land managers and the public fostered a special session at the 1988 Annual Meeting of the Society for Range Management which dealt with the successful management of public rangelands (Hall and Hampton 1988). The need to communicate the broader concepts of range management within and without NFS was also identified in the National Range Workshop (USDA Forest Service 1987a). This need to enhance communication was also recommended by the 1985 National Range Conference which brought together ranchers, range professionals, agribusiness leaders, environmentalists, producer associations, and others interested in rangelands. Specifically, the group recommended that efforts be undertaken to inform the public with accurate and unbiased information about rangeland uses (Dunlop 1987). This recommendation stressed that the public needs to know and understand that the benefits achieved through proper livestock grazing practices include sustained resource values, such as soil productivity and water quality, wildlife habitat, threatened and endangered flora and fauna, ecological diversity, and forage production for domestic and wild herbivores (Dunlop 1987).

Research Needs

Increased urbanization in the United States will mean that a growing percentage of the population will have little or no direct contact with natural resource management. In California where urbanization is proceeding rapidly, public information and education programs for kindergarten through 12th grade are needed to demonstrate the relevance of California's natural resources to the sustained well-being of urban populations (California State Board of Forestry, Committee on Research 1987). At the university level, Kennedy (1987) stressed that the increased interaction between resource managers and the public makes it even more critical that range conservation students be better educated and role-modeled to understand, appreciate, and master the internal politics of decision-making.

MULTIRESOURCE AND MULTI-AGENCY PLANNING

The management of range vegetation to produce multiple resource outputs was a concern raised by resource managers (USDA Forest Service 1988b). The need to manage forest and rangelands for wild and domestic herbivores was stressed by wildlife and range managers (Flather and Hoekstra in press, USDA Forest Service 1988b). Extensive resource management was seen as an efficient way to ensure water quantity and quality from forest and rangelands (Guldin in press). Not only are these problems multiple-resource oriented, but they are also multi-agency, as land ownerships often form a checkerboard pattern on the landscape.

Issues

The need to address range management from a multiple output perspective has been stressed in this chapter. On public lands, resource managers were concerned that the need to plan for the production of a mix of resource outputs from the land base was not being adequately addressed (Flather and Hoekstra in press, USDA Forest Service 1988b). Problems associated with the timing of management activities or the spatial distribution of these management activities are given insufficient attention because of insufficient time or personnel, or lengthy planning horizons. The loss of habitat on private lands for wildlife species places an increasing importance on nearby public lands to supply food, cover, and water. These remaining lands may have previously supplied only a portion of the total annual feed mix for these wildlife species, and now must supply a year-round feed mix. Examples can be given also where recreational developments on public lands force wildlife onto private lands, resulting in a seasonal forage deficiency, or increased crop damage. Conflicts also exist between wildlife, livestock grazing, and mineral development, and between water rights authority and wildlife in wetland areas. The Forest Service and the BLM must manage for a multiple set of resource outputs, and planning becomes increasingly important to resolve objectives for land management.

Many private landowners are in agreement with the multiple use concept but are concerned with its implementation (Grazing Lands Forum 1987). Specifically, issues of concern included poor enforcement of vandalism laws on private land, economic pressures to convert agricultural lands to developed uses, lack of cooperation between state and federal agencies concerning fish and wildlife habitat, allocation of much of agency funds for single-use management, and economic returns favoring commodity over noncommodity uses (Grazing Lands Forum 1987).

Government crop programs which temporarily change the vegetation composition have an impact on the mix of outputs that can be produced from a landscape composed of many different ownerships (Joyce and Skold 1988). These programs impact the forage and habitat for grazers and browsers, water runoff, and habitat for wildlife. The most recent program, the Conservation Reserve Program, will increase permanent vegetation cover for 10 years by 45 million acres (Chapter 2). State wildlife and fish managers saw this shift in vegetation cover as potentially benefiting small game, and in some places, big game. For the duration of the contract, this land cannot be grazed by livestock. Many questions concerning the impact of this program and future agricultural programs arise. Because these lands potentially represent

a large supply of forage, a concern has been raised on the potential impact on the livestock sector, and on releasing this forage supply at the end of the contract period. In addition, previous research suggests that any gains in wildlife populations would be jeopardized if cover were to shift dramatically after the program was ended (Joyce and Skold 1988).

Opportunities

Many successful examples can be cited where diverse, and often conflicting, interests have been brought together to arrive at common understanding and consensus in planning and implementing multiple uses. These examples include the Coordinated Resource Management Planning programs, the Experimental Stewardship Program, the Northwest Watershed Improvement Coalition, and the Oregon Watershed Improvement Coalition (Demarchi 1988, Grazing Lands Forum 1987).

Oregon range evaluation project—a case study in multiresource planning.—The Accelerated Range Program was initiated to conduct large-scale testing to confirm or adjust multiresource assumptions made in a nationwide study of rangeland productivity (Sanderson et al. 1988). The Grant County Resource Council proposed that Grant County be designated an "evaluation area" under the Forest and Rangeland Renewable Resource Planning Act, and in 1976, Congress appropriated $1.4 million to initiate the Oregon Range Evaluation Project (EVAL). The objective of EVAL was to determine the most cost-effective way to increase herbage and browse for livestock and to determine the effects of range management strategies on water quantity and quality and the consequences for the local economy (Sanderson et al. 1988).

The EVAL project was divided into four major elements: (1) Implementation—selecting private landowners to cooperate with EVAL, developing coordinated resource management plans, and establishing range management practices on public and private land; (2) Maintenance—maintaining the improvements adequately over the study period; (3) Monitoring—collecting baseline data and evaluating the effects of grazing management strategies on environmental, economic, and social resources, and (4) Reporting—providing the research results to all parties (Sanderson et al. 1988). The Forest Service (including the NFS, the State and Private Forestry, and Research) was the lead agency. Primary cooperating agencies and groups included the SCS, the Agricultural Stabilization and Conservation Service, the BLM, Oregon Department of Forestry, Oregon Department of Fish and Wildlife, Oregon State University Extension Service, and private landowners. Many other organizations and institutions cooperated.

The success of the EVAL project is marked by the excellent interagency cooperation and the cooperation provided by the private landowners. The project facilitated the development and implementation of 22 coordinated resource management plans and 21 long-term agreements. Over 1,000 range practices were established on 58,000 acres of private land and on 283,000 acres of public land. More ranchers are now requesting technical assistance than before the EVAL project, and some range practices are being initiated with the benefit of matching funds (Sanderson et al. 1988). The results of more than 100 theses, reports, and publications will provide private landowners, land managers, and environmental groups with economic and environmental information useful in future range management.

Experimental stewardship programs.—Cleary (1988) described the Modoc/Washoe Experimental Stewardship Program in northeastern California and northwestern Nevada as a successful example of coordinated resource management. Participants in this program viewed range management as more comprehensive than livestock management and chose to accommodate all public land uses where possible. Program participants included members from the livestock industry, timber industry, county governments, university range science departments, county Extension Service, SCS, resource conservation districts, Agricultural Stabilization and Conservation Service, Audubon Society, state game departments, state agricultural departments, Fish and Wildlife Service, the National Wildlife Federation, the BLM, and the FS. The long-term goal was to foster cooperation and coordination among the participants to achieve: (1) environmental improvement; (2) integrated and improved management of all ownerships; and (3) through improved management, long-term stability of the economy.

Management and Research Needs

The new and diverse demands being placed on range and forest ecosystems imply a continual need to further understand the ecology of these systems and to develop new management strategies to produce the multiple resource outputs demanded from these wildlands.

Opportunities to address multiple resource planning exist, particularly if state and county coordination can be strengthened (USDA Forest Service 1988b). Demarchi (1988) stated that coordinated resource management planning (CRMP) could be more successful if implemented after the development of a strategic land use plan in which decisions were made concerning the pattern of land use and how much of each use would be allowed within a planning unit. The CRMP focuses on the operational planning, that is, the how and by whom the goals identified in the strategic land use plan are to be achieved.

The desired situation with respect to multiple resource management, as reported in the Grazing Lands Forum (1987), was that all interested groups affected by this type of management would work together voluntarily to share information and arrive at consensus on management action. The recommendations to achieve this situation included: repeatedly invite all interested parties to participate in the planning process, expand the use of successful conflict resolution processes, inform and

assist potential users in conflict resolution, encourage educational and governmental institutions to emphasize multiple use values and coordinated planning, support the development of instructional aids for cooperative multiple use planning, and identify and hold meetings at demonstration sites (Grazing Lands Forum 1987). Opportunities exist also to increase the information transfer between research and management. Demonstration projects such as the EVAL project help increase the flow of research results to management.

Previous research has focused on single resource management and only recently, have multiresource projects begun to unravel the complexities of multiresource production. Research to increase, through cost effective measures, the output of multiple range resources has been recognized as an important research priority (Experiment Station Committee on Organization and Policy 1988, Society for Range Management 1989, Western Agricultural Research Committee 1985). Methods are needed to manipulate the plant community through biological mechanisms such as allelopathy, germplasm improvement, livestock, and introduced competition (Society for Range Management 1989). Also needed is an improved understanding of nutrient cycling processes and critical physiological characteristics of important forest and range plants (Western Agricultural Research Committee 1985).

Understanding and enhancing the productive capabilities of forest and range ecosystems was one of the research issues raised by the Agricultural Experiment Stations (Experiment Station Committee on Organization and Policy 1988). With respect to agricultural and forest land use, the stations saw the need to assess the implication of expanding wildlife enterprises and other recreation uses of agricultural, range, and forest lands, and to develop land use planning systems for the wildlife/rural/urban interface. The implications of changing land use on future forest and rangeland resource production were also identified as an urgent research topic by the California State Board of Forestry (1987). The future size, shape, and distribution of forest and rangeland area will be affected by landowner decisions. How zoning, taxes, population growth, and regulations affect these landowner decisions is not well-understood. Declines in timber and range production by the break-up of commodity-based ownership tracts and by restriction of management practices on and adjacent to residential parcels was a concern of the Board of Forestry (California State Board of Forestry 1987). Smaller parcels and expansion of the urban-wildland interface may reduce wildlife habitat area, create barriers to wildlife migration, enhance sediment losses, and complicate wildfire control problems. Research is needed to determine the long-term trends and to quantify the potential effects on timber and rangeland production, wildlife, rural services, and rural economics (California State Board of Forestry 1987).

Further, the impacts on vegetation are no longer just site-specific. An understanding is needed of the cumulative effects of management within a watershed or a region. Environmental changes, such as increased atmospheric deposition, increased carbon dioxide levels, or elevated air temperatures may have major effects on the structure, function, and productivity of forest and range ecosystems. Future research is needed to understand these possible effects and how forest and range management activities could be altered to sustain forest and range ecosystem health and productivity (Experiment Station Committee on Organization and Policy 1988, USDA Forest Service 1988a).

High-quality data bases and information management systems are needed to permit more knowledgeable policy discussion on land use alternatives (California State Board of Forestry 1988, Experiment Station Committee on Organization and Policy 1988, Flather and Hoekstra in press, USDA Forest Service 1988b). With respect to rangelands, information about the type and condition of vegetation is not complete for all ownerships. This lack of information limits an assessment of the range resource. The Agricultural Experiment Stations identified needed research to understand the biological and ecological concepts applicable to multiuse management of rangelands and pasturelands, and to develop information systems and decision models for users of these lands (Experiment Station Committee on Organization and Policy 1988).

The low economic return on rangelands influences its placement in research priorities. In evaluating the potential success of biological control on pasture/range species, range plants receive a lower priority in research (USDA Agricultural Research Service 1984). In prioritizing the 21 research initiatives, the Agricultural Experiment Stations ranked Productivity of Range and Pastureland the 18th priority, surpassing the initiative on Forest Productivity by only 1 rank (Experiment Station Committee on Organization and Policy 1988). As more resources are demanded from these lands, it will become increasingly important to understand the underlying ecological processes of rangelands.

MANAGEMENT OBSTACLES

Management obstacles are those factors that prevent implementation of effective management opportunities for the range resource. The most common obstacles identified by range resource managers were inadequate funding, inadequate staffing, lack of qualified personnel, and lack of knowledge. These factors were also the most common obstacles cited by wildlife and fish managers (Flather and Hoekstra in press).

Inadequate funding affects all aspects of range management and research. Lack of funds and technology affect the number of management alternatives available to the resource manager. Between 1980 and 1985, in constant (inflation adjusted) dollars, the Forest Service budget declined by 16%, funding for range management on national forests declined by 25%, funding for wildlife and fish management on national forest declined by 9% (Barton and Fosburgh 1986).

Although lack of funding is often the cause for the lack of personnel, declining enrollments and number of graduates with natural resource degrees has resulted in

a short supply of potential resource managers. In addition, specialists for threatened and endangered species are also in short supply. An interdisciplinary approach in planning requires management experts in a variety of fields. Traditional attitudes of personnel/public limit new and creative approaches to land management.

The need for knowledge to provide the best management was discussed in the opportunities sections above. Overcoming this lack of knowledge requires research and the transfer of research results to managers. Knowledge also refers to the awareness and understanding of the public's attitudes and values with respect to the range resource. The need for increased communication between resource managers and the public was recognized as very important. The public must understand the production requirement for a mix of resource outputs and the proposed management for that land. This shared understanding is important to resolve resource conflicts. Public information and education programs, including demonstration projects, are opportunities to increase the communication links. The demands on the range resource are increasingly broadening which expands the number of people and interests using the range resource. Resource managers need to be aware of the changing demand on the range resource to better meet the public's needs.

SUMMARY

Potential shifts in forage production could significantly affect the availability and utilization of forage by wild and domestic herbivores. Increasing demands for recreation and water production from public lands will influence range management. The expected rise in forage demand, coupled with relative declines in public forage and irrigated pastures, suggests that range management on private lands will intensify. A future in which resource use intensifies poses the possibility that our Nation's ecosystems will not likely improve in condition or productivity. The management issues associated with the range resource are now broader than livestock grazing.

Management issues are grouped into four categories: the management of range vegetation; the management of grazers and browsers, both wild and domestic; social issues; and planning. Vegetation management issues revolved around providing the type of vegetation on public and private lands necessary for the production of multiple outputs. Problems ranged from inadequate seasonal forages for wild and domestic herbivores, the expired life-time of existing range improvements, reductions in habitat and forage availability, riparian vegetation, and the control of undesirable plants. Opportunities in vegetation management include grazing systems, stream management for riparian areas, the interseeding of native/introduced species to lengthen the seasonal availability of forage, and the use of biological control agents including livestock. The development and adoption of management practices and technologies will become significant factors in the future of the range resource. Research issues included the lack of knowledge about the ecology of vegetation and the need for technology transfer from research to management.

The need to provide food and habitat for wildlife, wild horses and burros, and livestock raises the issue of the management of grazers and browsers. The number of animals, the seasonal distribution of these animals, the availability of suitable grazers and browsers for each range ecosystem, and the management of these animals on public lands are components of this management issue. Opportunities exist to increase the efficient use of range and forest vegetation and control undesirable plants through the management of multiple species of grazers and browsers.

The value of the natural environment is increasingly in the public's mind, and society's ideas about range will determine the future use of this resource. These social issues point to the need for increased communication between land managers and the public, and for adequately trained range managers. Opportunities exist to communicate the values received from a healthy plant association, the livestock role in maintaining the desired ecological status, and an understanding that proper livestock grazing practices can achieve desired resource benefits.

Whether legally mandated or profit motivated, the desire to produce a mix of resource outputs from forest and rangelands raises the issue of planning. Problems in planning include the design of management for multiple resources, coordination between adjacent or checkerboard ownerships, coordination of timing or spatial distribution of management activities, insufficient planning time, difficulties of quantifying the relationship between current actions and future consequences, economic pressures to convert nonfederal agricultural lands to developed uses, and economic returns favoring commodity over noncommodity uses. Many successful examples can be cited where diverse, and often conflicting, interests have reached consensus in planning and implementing multiple uses.

Research is needed to increase, through cost effective measures, the output of multiple resources from rangelands and forests. Methods are needed to manipulate the plant community through biological mechanisms. Long-term productivity will be sustained only with an improved understanding of nutrient cycling processes, critical physiological characteristics of important forest and range plants, and the response of ecosystems to disturbance.

An understanding is needed of the cumulative effects of management within a watershed, forest, or a region. The future size, shape, and distribution of forest and rangeland area will be affected by land management decisions, and how these decisions are affected by zoning, taxes, population growth, and regulations is not well-understood. Smaller parcels and expansion of the urban/wildland interface may reduce wildlife habitat area, create islands of suitable forage for grazing, create barriers to wildlife migration, increase sediment losses, and complicate wildfire control problems. Research is needed to determine the long-term trends of land use

changes and to quantify the potential effects on rangeland production, wildlife, rural services, and economics. Toward this end, a need exists to develop high-quality data bases, information management systems, and decision models to permit more knowledgeable policy discussion on land use alternatives.

Management obstacles are those factors that prevent implementation of effective management opportunities for the range resource. The most common obstacles identified by range managers were lack of knowledge, inadequate funding, inadequate staffing, and lack of qualified personnel. The actualization of the opportunities for range management requires a commitment of those involved in natural resource management.

CHAPTER 7: IMPLICATIONS OF THE RANGE ASSESSMENT FOR FOREST SERVICE PROGRAMS

RELATIONSHIP BETWEEN ASSESSMENT AND PROGRAM

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), as amended, directs the Secretary of Agriculture to prepare a comprehensive, long-range Assessment of the Nation's renewable resources and to develop a Program for Forest Service activities. The technical supporting documents for range, timber, wildlife, recreation, minerals, and water identify opportunities to balance supplies of renewable resources to meet projected demands. The Assessment presents the findings of these technical supporting documents and summarizes the implications for the Program. Opportunities outlined in the Assessment (Darr in press) help set the scope of the national goals to guide development of the Program. The Program recommends courses of action, based on the findings of the Assessment, for the management and administration of the National Forest System (NFS), for Forest Service Research, and for assistance to state forestry organizations and other cooperators through State and Private Forestry activities. This chapter discusses briefly the implications of this Range Assessment to the 1990 Program of the Forest Service.

FOREST SERVICE PROGRAMS

Forest Service activities are divided into three major areas: National Forest System, State and Private Forestry, and Research. The NFS manages 156 National Forests, 19 National Grasslands, and 16 Land Utilization projects covering a total of 191 million acres. The State and Private Forestry program extends financial and technical assistance to states, and through them, to private landowners, in the application of forest management practices on private lands. Eight Forest Service Experiment Stations and a Forest Products Laboratory conduct research to solve important problems related to the protection, management, and wise use of forest and rangelands through development of knowledge and technology.

The Forest Service receives operating funds from Congress and from various cooperator deposits (USDA Forest Service 1987d). Operations such as timber sales on NFS lands generate receipts. Other receipts from these lands are collected from grazing and recreation fees and mineral leases and permits. In 1986, $1.32 billion was received from users of NFS lands, while expenditures totaled $1.71 billion. Eighty-three percent of the revenue in 1986 was from timber receipts which included cash, deposits, and roads in lieu of cash. The second largest source of revenue was receipts from mineral leases, royalties, sales, and bonus bids. Grazing leases provided 1% of the Forest Service revenue (fig. 59).

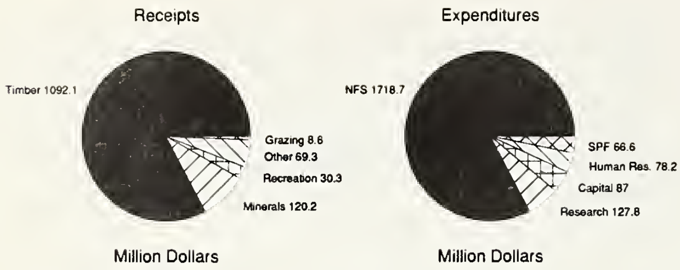
Expenditures for the NFS measured nearly 83% of the Forest Service budget. The Working Capital Fund which is used to replace vehicles and heavy equipment amounted to 4% of the expenditures; 6% of the expenditures were allocated to Research, and 3% to State and Private Forestry. Human Resource Programs, which expended 4% of the Agency budget, provided job opportunities and training for youths, the unemployed, underemployed, economically disadvantaged, and the elderly, while carrying out high-priority conservation work.

The work force within the Forest Service is distributed across program areas as follows: 92.2% in NFS, 7.3% in Research, and 0.5% in State and Private Forestry (fig. 60). Technical occupations account for 57.3% of the work force; the largest portion is for forestry technicians. Professional staff account for 23.7% of the Agency's work force; foresters and civil engineers are the largest of the professional occupations.

IMPLICATIONS FOR THE 1990 PROGRAM

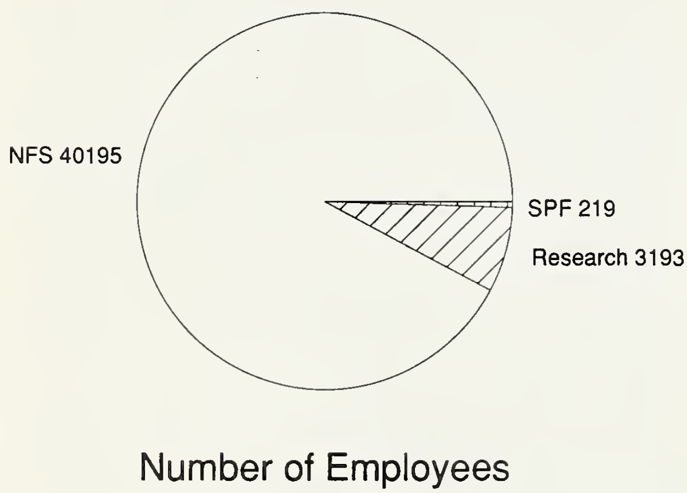
The 1985 Program provided guidance for the administration of NFS, State and Forestry Programs, Research, and other Forest Service activities through 2030 (USDA Forest Service 1986a). The 1985 RPA Program identified a number of resource options recommended by the Secretary of Agriculture to permit consideration of both the current federal deficit situation and the Forest Service long-term resource goals. These options responded to the long-term renewable resource needs of the American people as described in the Assessment supplement (USDA Forest Service 1984a). The 1985 Program recognized the importance of nonfederal lands in meeting long-term resource needs and emphasized the contribution needed from research to take full advantage of the national resource opportunities.

The specific goal for range identified in the 1985 Program was to "provide forage to promote the economic stability of dependent livestock producers and rural



Source: USDA, Forest Service (1987)

Figure 59.—Distribution of receipts and expenditures by Forest Service program area for 1986.



Source: USDA, Forest Service (1987)

Figure 60.—Distribution of 1986 workforce by Forest Service program area: National Forest System (NFS), State and Private Forestry (SPF), and Research.

communities by maintaining the current level of forage production on National Forest System Lands, and expanding this level of production where cost effective. Develop and apply technology, where cost effective, to improve range conditions and to coordinate livestock and other multiple uses of rangeland'' (USDA Forest Service 1986a).

The first implication of this 1989 Range Assessment for goals set forth in the 1990 Program is that the goals for the range resource must be broadened beyond the traditional value of livestock grazing. Specifically, range resource should be typified by healthy vegetation, the protection of soil and water, the presence of riparian and upland habitat for fish and wildlife species, a land that responds effectively to management improvements, a resource that provides economic benefits and meets public desires for open space. The goal of the Forest Service Program must be directed toward fostering this vision on public lands, and serve as an example for the management of private lands.

National Forest System

Livestock grazing of range forage on NFS lands will continue to contribute to the social and economic well-being of rural communities. Although these traditional values remain, new demands must be accommodated if the Forest Service is to keep pace with changes in society and maintain range productivity. Many demands for the use of range vegetation are recognized in addition to livestock grazing: wildlife habitat, outdoor recreation, hunting, scenery, fresh air and open spaces, places for wild horses to roam, soil stability, water quality and quantity, and minerals.

The Range Assessment has implications for the NFS Program in these general areas:

1. A merging of range science with grazing management so that livestock use becomes a tool for improving vegetation and promoting ecological diversity for a wider variety of uses.
2. Urbanization of areas within and adjacent to the national forests is resulting in land conversion from agricultural use to residential and commercial use. There is a need to resolve the resulting social conflicts, the loss of wildlife habitat and the reduction in opportunities to graze on public lands.

The ultimate goal is to produce quality range vegetation and water on all national forests and grasslands for all resource users within the context of meeting Forest Plan objectives and management requirements. One of the implications of the Wildlife and Fish Assessment is that NFS lands are expected to become more important in the protection and preservation of certain wildlife and fish species, in the preservation and protection of vegetation communities that comprise important wildlife and fish habitat, and in providing wildlife and fish recreational opportunities (Flather and Hoekstra in press). An additional implication of the Wildlife and Fish Assessment is the need to integrate wildlife and fish management considerations into comprehensive land management plans. This challenge will require a commitment across resource lines to provide multiple resource outputs from NFS lands. The future increased demand for range forage will necessitate a cost-efficient and productive grazing program designed to meet future grazing and multiple use needs.

Increased urban and recreational area expansion surrounding NFS lands will require coordinated resource management across a number of ownerships. Without the ability to use interdependent public range, the associated privately owned pasture and cropland will lose their value for agriculture and gain a relatively higher value for commercial and residential development. Because wildlife and fish are mobile resources, one of the major management concerns identified on

public lands was the constraint associated with managing this mobile resource over a land base with intermingled and fragmented land ownership (Flather and Hoekstra in press). Coordinated resource management has been successfully used to address these multiple ownership planning problems (Chapter 6).

The Forest Service must continue to take steps toward a broader view of range management and range management practices—beyond traditional forage and livestock benefits—to an overall perspective that includes a full range of values. To meet these new challenges, the Forest Service is reviewing its range management policy, objectives, and delegations of authority (Comanor 1988a). This examination includes day-to-day operations and methods of range analysis and planning. A full range of values are contemplated to measure range management goals and accomplishments in terms that more accurately portray, both to the administrator and to the public, the broader scope of range vegetation management.

State and Private Forestry

Technical and financial assistance is provided to states by the State and Private Forestry programs to help protect and improve the productivity and management of the nonindustrial private forest lands (USDA Forest Service 1987d). The Cooperative Forestry Assistance Act of 1978 authorized the Secretary of Agriculture to cooperate with state foresters and provide assistance in a variety of forest-related activities: (1) fire prevention and control, (2) prevention and control of forest insects and diseases, and (3) forest management and utilization (USDA Forest Service 1987d). The latter activity can benefit wildlife and range programs through habitat and range improvement programs.

The Range Assessment identified that much of the increase in range forage supply will come from private lands. The Range Assessment also assumed that these private lands will be managed more intensively. The profitability of ranching will determine the actual supply from private lands. The Soil Conservation Service might consider the extent to which technical assistance would facilitate range forage production on private lands. On forested lands, technical assistance through State and Private Forestry programs could expand the implementation of timber management practices in an agroforestry context. The need to diversify outputs from ranching/farming enterprises has led to an interest in multiple use management (Chapter 6). Technical assistance is needed to facilitate the implementation of multiple use management practices on private lands. This implication suggests the need to coordinate resource management among agencies providing technical assistance on rangeland such as the Soil Conservation Service, and the Extension Service.

Forest Service Research

Forest Service research comprises 9 major areas of research: forest fire and atmospheric sciences; forest insect and disease; forest inventory and analysis; renewable resources economics; trees and timber management; watershed and rehabilitation; wildlife, range, and fish habitat; forest recreation; and wood products and harvesting. As required by Title XIV of the Agriculture and Food Act of 1981, Forest Service research is planned jointly with the 61 forestry schools through the USDA Cooperative State Research Service. Research goals are directed toward increasing the productivity of public and private forest and rangeland while maintaining or enhancing environmental quality.

In an official policy paper released by the Secretary's (Agriculture) Office of Science and Education on March 22, 1982, the following responsibilities were stressed by the Administration and Congress as appropriate Federal agricultural research responsibilities:

a. Fundamental approaches that are beyond the risk-taking capacity of the private sector.
b. Areas needing systems approaches, high-cost integrated multidisciplinary approaches, or mega-problems (national/global scope) which are beyond the capability of other sectors.
c. Programs that other areas will not address or which cannot be equally or better accomplished elsewhere. This particularly relates to industry capability and responsibility.
d. Programs which because of their high cost, high priority, or regional, national, or global scale require government management and leadership but do not preclude participation by other sectors.
e. Programs mandated by Congress.
f. Programs required by U.S. Department of Agriculture, such as technical and educational support for action agencies.

Based on this policy statement, the 1985 Program Update concluded that high-priority Forest Service research should be continued, with focus on new research such as biotechnology and more fundamental research, improved information and analytical systems for analysis of domestic and international timber supply-and-demand trends, and research requiring major integrated multidisciplinary efforts of national or international scope. Other major focus points included economic efficiency of forest resource management, atmospheric deposition, water quality and yield, and forest resource protection from fire, insects, and disease (USDA Forest Service 1986a). Research direction identified for range was as follows:

> Greater productivity of range resources is needed and can be realized through genetic improvement of range plants, broader understanding of range ecology, improved grazing management systems, and development of environmentally safe noxious weed control technology.

The Program identified specific opportunities to increase rangeland productivity through research such as forage plant improvement, integration of forage management with other land management strategies, and use of fire for improving rangeland growing conditions (USDA Forest Service 1986a).

This assessment points out the need for greater productivity recognizing the broader demands by the American people on the range resource. Range ecosystems have been managed on the basis of low inputs. Future resource output demands from these systems will require an intensification of management or these systems will not likely improve in condition or productivity. A clear need exists to increase our understanding of basic biological and economic relationships for the purpose of developing new technology to integrate and enhance range resource values on intensively managed rangelands. Low-cost range improvement practices are needed in areas where profit is low. The implications to over-use of the range resources are long-term, particularly in the arid west.

This assessment points out several range research needs:

1. the need to develop vegetation management for multiple resource production from rangelands,
2. the need to define opportunities for multiple grazing species management of rangelands,
3. the need to define the ecological and economical opportunities for using livestock as a vegetation management tool in a broader number of ecosystems,
4. the need to develop quantitative methods to analyze the economic and environmental consequences of increasing multiple resource demand from rangelands on a site-specific basis and at larger scales; this includes the need for better resource inventories,
5. the need to quantify and monitor local and regional impacts of multiple resource management across ownerships.

Range vegetation management must be based on ecological principles and be defined in terms of species composition, ecological condition, and the ability to sustain use. Research needs include understanding of the ecology of rangelands and the ecosystem's response to natural and human-caused disturbances. The nature of human-caused disturbances includes intentional management as well as unintentioned human disturbances, such as the introduction of undesirable plants. The role that biotechnology can play in controlling these disturbances is an important range research goal, as is the role that range vegetation can play in providing genetic material with desired attributes such as drought or pest resistance. The unique aspects of the riparian zone are also a research topic of high priority. Opportunities exist to integrate the disciplines of timber, watershed, wildlife, range, fisheries, and soils research to address the complex interrelationships among plants, animals, and physical factors in riparian zones.

The management of multiple species of grazers and browsers can increase the efficient use of range and forest vegetation. Research needs in this area include the compatibility of animal types, forage requirements, and grazing management systems. Additional research is needed on the economics of multiple species grazing. The role of livestock as a management tool offers opportunities to attain land management objectives, particularly where environmental concerns have shifted the availability of management practices.

As the intensity of land use increases, so does the need to develop quantitative methods to analyze the consequences of increasing resource demand from rangelands on a site-specific basis and at larger scales. The urban encroachment on rangeland not only increases the conflicts between urban and range land activities, but places increased importance on rangeland for wildlife, livestock, recreation, and water production. Linking site-specific activities within the context of other land uses/management activities at a larger scale (such as a watershed, forest, across ownerships, or within a region) will be important in evaluating the consequences of land management activities on the resource outputs from rangeland. Risser et al. (1984) summarized the need for multiple-scale resource analyses by concluding that informed resource planning can no longer be based solely at the site level, but must develop methodologies for examining the interaction of resources across larger geographic areas or landscapes. Future land management decisions will determine the size, shape, and distribution of parcels of land with forest and range vegetation, and these attributes will determine their future viability for resource production.

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APPENDIX A: COMMON AND SCIENTIFIC NAMES OF PLANTS (PRIMARY SOURCE: USDA SOIL CONSERVATION SERVICE. 1982. NATIONAL LIST OF SCIENTIFIC PLANT NAMES. SCS TP 159 2 VOL.)

Common name	Scientific name
Acacia	*Acacia* spp.
Alder	*Alnus* spp.
Apache pine	*Pinus engelmannii*
Arizona cypress	*Cupressus arizonica*
Ash	*Fraxinus* spp.
Aspen	*Populus tremuloides*
Baldcypress	*Taxodium distichum*
Balsam fir	*Abies balsamea*
Barbwire Russian thistle	*Salsola paulsenii*
Basswood	*Tilia* spp.
Beech	*Fagus grandifolia*
Birch	*Betula* spp.
Bitterbrush	*Purshia tridentata*
Black grama	*Bouteloua eriopoda*
Black oak	*Quercus kelloggii*
Blackbrush	*Coleogyne ramosissima*
Blackgum	*Nyssa sylvatica* var. *sylvatica*
Blue grama	*Bouteloua gracilis*
Blue oak	*Quercus douglasii*
Blue spruce	*Picea mariana*
Bluestem	*Andropogon* spp., *Bothriochloa* spp., *Scizachyrium* spp.
Bristlecone pine	*Pinus aristata*
Buffalo gourd	*Cucurbita foetidissima*
Buffalograss	*Buchloe dactyloides*
Buffelgrass	*Cenchrus ciliaris*
Bulrush	*Scirpus* spp.
Burroweed (white bursage)	*Ambrosia dumosa*
Bursage	*Ambrosia deltoidea, A. dumosa*
Canada thistle	*Cirsium arvense*
Canyon live oak	*Quercus chrysolepis*
Ceanothus	*Ceanothus* spp.
Ceniza	*Leucophyllum frutescens*
Cheatgrass	*Bromus tectorum*
Chestnut oak	*Quercus prinus*
Chihuahua pine	*Pinus leiophylla*
Coast live oak	*Quercus agrifolia*
Coastal true fir	*Abies amabilis, A. procera*
Cordgrass	*Spartina patens, S. pectinata*
Cottonwood	*Populus fremontii*
Creosotebush	*Larrea tridentata*
Crested wheatgrass	*Agropyron desertorum*
Cypress	*Taxodium* spp., *Cupressus*
Curly mesquite	*Hilaria belangeri*
Dalmatian toadflax	*Linaria dalmatica*
Diffuse knapweed	*Centaurea diffusa*
Diggerpine	*Pinus sabiniana*
Douglas fir	*Pseudotsuga menziesii*
Dyers woad	*Isatis tinctoria*
Eastern hemlock	*Tsuga canadensis*
Eastern white pine	*Pinus strobus*

Common name	Scientific name
Elm	*Ulmus* spp.
Engelmann spruce	*Picea engelmannii*
Fescue	*Festuca* spp.
Fir	*Abies* spp.
Flowering dogwood	*Cornus florida*
French broom	*Cytisus monspessulanus*
Galleta	*Hilaria* spp.
Gopher plant	*Euphorbia lathyris*
Gorse	*Ulex europaenus*
Grama	*Bouteloua* spp.
Grand fir	*Abies grandis*
Greasewood	*Sarcobatus vermiculatus*
Green ash	*Fraxinus pennsylvanica*
Guayule	*Parthenium argentatum*
Gumweed	*Grindelia* spp.
Halogeton	*Halogeton glomeratus*
Hawthorn	*Crataegus* spp.
Hemlock	*Tsuga* spp.
Hickory	*Carya* spp.
Hoary cress	*Cardaria draba*
Interior live oak	*Quercus wislizenii*
Italian thistle	*Carduus pycnocephalus*
Jack pine	*Pinus banksiana*
Jeffrey pine	*Pinus jeffreyi*
Jojoba	*Simmondsia chinensis*
Juniper	*Juniperus* spp.
Kentucky bluegrass	*Poa pratensis*
Kudzu	*Pueraria lobata*
Larch	*Larix laricina*
Laurel oak	*Quercus laurifolia*
Leafy spurge	*Euphorbia esula*
Lehmans lovegrass	*Eragrostis lehmanniana*
Limber pine	*Pinus flexilis*
Little bluestem	*Schizachyrium scoparium*
Live oak	*Quercus virginiana*
Loblolly pine	*Pinus taeda*
Lodgepole pine	*Pinus contorta*
Longleaf pine	*Pinus palustris*
Longleaf uniola	*Chasmanthium sessiliflorum*
Mangrove	*Avicennia* spp.
Maple	*Acer* spp.
Matchweed (Snakeweed)	*Gutierrezia sarothrae*
Mesquite	*Prosopis juliflora*
Mountain big sagebrush 'Hobble Creek	*Artemesia tridentata* ssp. *vaseyana*
Mountain hemlock	*Tsuga mertensiana*
Musk thistle	*Carduus nutans*
Northern red oak	*Quercus rubra*
Oak	*Quercus* spp.
Overcup oak	*Quercus lyrata*
Paloverde	*Parkinsonia florida, P. microphylum*
Paper birch	*Betula papyrifera*
Pecan	*Carya illinoensis*
Perennial peppergrass	*Lepidium latifolium*
Perennial sowthistle	*Sonchus arvensis*
Persimmon	*Diospyros virginiana*
Pine	*Pinus* spp.
Pinehill bluestem	*Schizachyrium scoparium* var. *divergens*

Common name	Scientific name
Pinyon pine	*Pinus edulis*
Plumeless thistle	*Carduus acanthoides*
Poison hemlock	*Conium maculatum*
Pond cypress	*Taxodium distichum*
Ponderosa pine	*Pinus ponderosa*
Port Orford cedar	*Chamaecyparis lawsoniana*
Post oak	*Quercus stellata*
Prickly pear cactus	*Opuntia* spp.
Purple starthistle	*Centaurea calcitrapa*
Rabbitbrush	*Chrysothamnus* spp.
Red maple	*Acer rubrum*
Red pine	*Pinus resinosa*
Red spruce	*Picea rubens*
Redwood	*Sequoia sempervirens*
Russian knapweed	*Centaurea repens*
Russian thistle	*Salsola iberica*
Sagebrush	*Artemisia* spp.
Saguaro	*Carnegiea* spp.
Saint Johnswort	*Hypericum perforatum*
Saltbush	*Atriplex* spp.
Saltcedar	*Tamarix pentandra*
Saltgrass	*Distichlis spicata*
Sand bluestem	*Andropogon*
Saw grass	*Cladium jamaicense*
Saw palmetto	*Serenoa repens*
Scotch broom	*Cytisus scoparius*
Sedge	*Carex* spp.
Serviceberry	*Amelanchier alnifolia*
Shadscale	*Atriplex confertifolia*
Shin oak	*Quercus mohriana*
Shortleaf pine	*Pinus echinata*
Side oats grama	*Bouteloua curtipendula*
Silver buffaloberry	*Shepherdia argentea*
Sitka spruce	*Picea sitchensis*
Skunkbush sumac	*Rhus trilobata*
Slash pine	*Pinus elliottii*
Slenderflower thistle	*Carduus tenuiflorus*
Smooth brome	*Bromus inermis*
Snakeweed	*Gutierrezia sarothrae*
Snowberry	*Symphoricarpos albus*
Spotted knapweed	*Centaurea maculosa*
Spruce	*Picea* spp.
Subalpine fir	*Abies lasiocarpa lasiocarpa*
Subterranean clover	*Trifolium subterraneum*
Sugar maple	*Acer saccharum*
Sugar pine	*Pinus lambertiana*
Sugarberry	*Celtis laevigata*
Swamp tupelo	*Nyssa sylvatica* var. *biflora*
Sweet bay	*Magnolia virginiana*
Sweetgum	*Liquidambar styraciflua*
Sycamore	*Platanus* spp.
Tall larkspur	*Delphinium* spp.
Tansy ragwort	*Senecio jacobeae*
Tarbush	*Flourensia cernua*
Three awn	*Aristida* spp.
Tobosa	*Hilaria mutica*
Tupelo	*Nyssa* spp.
Valley oak	*Quercus lobata*
Water hickory	*Carya aquatica*

Common name	Scientific name
Water oak	*Quercus nigra*
Water tupelo	*Nyssa aquatica*
Western hemlock	*Tsuga heterophylla*
Western juniper	*Juniperus occidentalis*
Western red cedar	*Thuja plicata*
Western white pine	*Pinus monticola*
Wheatgrass	*Agropyron* spp.
White oak	*Quercus alba*
Willow	*Salix* spp.
Willow oak	*Quercus phellos*
Winterfat	*Eurotia lanata*
Wiregrass	*Aristida stricta*
Yaupon	*Ilex vomitoria*
Yellow birch	*Betula alleghaniensis*
Yellow popular	*Liriodendron tulipifera*
Yellow starthistle	*Centaurea solstitialis*

APPENDIX B: FOREST AND RANGE ECOSYSTEMS

INTRODUCTION

Classification systems have been developed to describe the diversity of vegetation across the Nation's landscape. In this document, forest and range vegetation will be described using the Forest and Range Environmental System (FRES) (Garrison et al. 1977). The relationship between the Society of American Forester's forest types and FRES is presented in Eyre (1980). More detailed forest and range classifications have been developed for specific regions, e.g., for western forest ecosystems (Alexander 1985, Franklin and Dyrness 1973, Johnston 1987, Mauk and Henderson 1984, Pfister et al. 1977) and for eastern forests ecosystems (Braun 1964). FRES types were not defined for Alaska and Hawaii. Forest and rangelands in Alaska have been described by McNicholas (1983). Hawaiian ecosystems have been described by Stone and Scott (1987).

A brief description of the FRES ecosystems is given below. The description of each ecosystem is taken from Garrison et al. (1977), unless otherwise referenced. The broad geographic locations of the FRES ecosystems are mapped in figure 2, and defined in table 1 in Chapter 1. Some of the diverse resource outputs from these ecosystems have been presented in tables 2, 3, and 4 in Chapter 1. More detailed information about fauna found on the nation's forest and rangelands can be found in Flather and Hoekstra (in press) and on timber products from forest lands in Haynes (in press).

EASTERN FOREST ECOSYSTEMS

White-Red-Jack Pine and Spruce-Fir Ecosystems

These forest ecosystems occur in the northeastern part of the Northern region (numbers 10 and 11 in fig. 2). Valued primarily for their timber production, these ecosystems also provide habitat to a variety of wildlife including white-tailed deer, moose, great horned owl, spruce grouse, and ruffed grouse (DeGraaf and Rudis 1986, Eyre 1980). The white-red-jack pine ecosystem also provides habitat for the endangered eastern timber wolf, peregrine falcon, and Kirtland warbler. Insects are important in the nutrient cycling and energy flow of the spruce-fir ecosystem. The spruce budworm, the eastern spruce beetle, and the black-headed budworm feed on needle leaves, and at epidemic levels, may cause serious damage to the forest stand (Shelford 1963). Understory vegetation is predominately shrubs and forbs (Eyre 1980).

Maple-Beech-Birch and Aspen-Birch Ecosystems

These ecosystems commingle along the Canadian border of the Northern region (numbers 18 and 19 in fig. 2). Before European settlement, this area was covered with white-red-jack pine and spruce-fir ecosystems. Paper birch and aspen regenerate on sites disturbed by wildfire or human impact, and are usually succeeded by spruce-fir or pine types, depending upon the location (Eyre 1980). The understory vegetation is typically shrubs or forbs providing good habitat for ruffed grouse, white-tailed deer, and moose (DeGraaf and Rudis 1986), while the cleared areas converted to pasture provide forage for the dairy industry of this region.

Oak-Pine and Oak-Hickory Ecosystems

These ecosystems span the central part of eastern United States, occurring in both the Northern and Southern regions (numbers 14 and 15 in fig. 2). Oak-pine forests are characterized by a stand composition of 50% or more in hardwoods and 25-49% in southern pines, mainly shortleaf pine. Grass and forb production is low in oak-pine when tree density is high (Thill and Wolters 1979), but can exceed a half ton per acre when the overstory is reduced by thinning (Wolters et al. 1982). The oak-pine type provides habitat for game species such as white-tailed deer and wild turkey (DeGraaf and Rudis 1986). Six distinctive vegetation communities were defined in the oak-hickory type by Garrison et al. (1977). Under three of these types—the oak savanna, the mosaic of oak-hickory forest and bluestem prairie on the Ozark Plateau, and the Cross Timbers in Texas and Oklahoma—grasses and forbs contribute significantly to understory composition and production. Under proper management, forage production can exceed 2 tons per acre, providing valuable forage for beef operations (Crawford and Porter 1974). The oak-hickory ecosystem provides habitat for game species such as white-tailed deer and mourning dove (Evans and Kirkman 1981) and a number of endangered plants and animals, including the southern bald eagle, red wolf, and the red-cockaded woodpecker.

Loblolly-Shortleaf Pine Ecosystem

This forest ecosystem covers an extensive area in the northern part of the Southern region (number 13 in fig. 2). These forests are characterized by stands in which 50% or more of the stand is loblolly pine, shortleaf pine, or other southern yellow pines, singly or in combination. Because of the large geographic extent of this type, the remaining stand composition is filled with many different kinds of tree associates. The characteristic understory vegetation is a dense stand of hardwoods, shrubs, woody vines, and pine regeneration. Changes in stand

structure resulting from age and management impact the openness of the stand affecting forage production (Grelen 1978), species composition of birds (Hamilton and Yurkunas 1987, Whiting and Fleet 1987), and small mammal populations (Mullin and Williams 1987). Under an open canopy, pinehill bluestem contributes significantly to herbaceous production, and as the stand ages, longleaf uniola begins to dominate with a decline in herbaceous production (Halls and Schuster 1965). This type is prime habitat for white-tailed deer (Thill 1983), wild turkey, bobwhite, and mourning dove.

Longleaf-Slash Pine Ecosystem

This forest ecosystem rings the coastal edge of the Southern region (number 12 in fig. 2). Longleaf pine, slash pine, or both in a stand composition of 50% or more characterizes this ecosystem. Site and geographic location determine the remaining tree stand composition (Eyre 1980). Upland sites include flowering dogwood, other oaks, hickories, yaupon, persimmon, and hawthorn. Wetter sites may be associated with red maple, sweetgum, blackgum, water, and laurel oak. Under periodic flooding, associates will include baldcypress, pondcypress, blackgum, or water tupelo. Understory vegetation consists of grasses and shrubs. Understories in Louisiana, Mississippi, Alabama, and northwest Florida are dominated by bluestem grasses (Grelen 1978). Florida and Georgia sandhills and pine flatwoods have an understory dominated by wiregrass with other species including saw-palmetto (Grelen 1978). Because of the extensive understory of grass, this type is important for livestock grazing. A number of endangered plants and animals occur, including the red-cockaded woodpecker and the Florida panther. Bobwhite and wild turkey are important game birds. Intensive logging, land clearing with subsequent abandonment, fire suppression, and recently, clearcutting have converted many longleaf-slash communities to pure stands of loblolly or slash pine (Eyre 1980, Grelen 1978).

Oak-Gum-Cypress Ecosystem

This Southern region type is characteristic of river flood plains, the cypress savanna west and the mangrove swamps south of the Florida Everglades, and the eastern coast of Florida, Georgia, and the Carolinas (number 16 in fig. 2). Within the river flood plains, common tree associates are broad-leaved deciduous trees such as willow, maple, sycamore, cottonwood, and beech. The mangrove swamp provides habitat for white-tailed deer and many endangered species such as Florida manatee, brown pelican, bald eagle, hawksbill sea turtle, and Atlantic ridley sea turtle (Odum et al. 1982). The cypress savanna is dominated by needle-leaved deciduous trees and some broad-leaved evergreen or deciduous trees and shrubs. White-tailed deer commonly utilize these habitats, along with gray fox, gray squirrel, fox squirrel, and other small mammals. Wild turkey is an important game bird. The flooded areas provide habitat for ibises, cormorants, herons, egrets, and kingfishers. Endangered species include Bachman's warbler, Florida panther, and bald eagle. Much of this area has been converted to either cropland or pasture. In 1977, Garrison et al. (1977) estimated that only the wettest parts of this type remained in forest, about 10%.

Elm-Ash-Cottonwood Ecosystem

This riparian vegetation type forms narrow corridors on the lower terraces and flood plains of the Mississippi, Missouri, Platte, Kansas, Arkansas, and Ohio Rivers (number 17 in fig. 2). Low to tall broadleaved deciduous trees vary from open to dense stands. Common tree associates differ in the northern and southern extents. The cottonwood-willow stage is usually succeeded by birch, maple, and elm species in the north and sycamore, pecan, elm, sugarberry, or green ash species in the south (Eyre 1980). This type is utilized by waterfowl such as mallard and wood duck, and other birds such as American woodcock and mourning dove (Evans and Kirkman 1981).

WESTERN FOREST ECOSYSTEMS

Douglas-Fir Ecosystem

This forest ecosystem occurs in the Rocky Mountain, the Pacific North, and the California regions (number 20 in fig. 2). Douglas-fir in the coastal regions occurs with western hemlock and western redcedar, and is not usually classified as a climax species because it is moderately intolerant to the low-light intensities characteristic of these forests. Within the Rocky Mountains, Douglas fir tends to occur in pure stands (Mitchell 1983). Understory vegetation varies with the topographic, climatic, and edaphic conditions of the site and ranges from grass-dominated communities to sites densely vegetated with shrubs to sites with little understory vegetation (Mitchell 1983). Mature stands offer little browse or forage, however forest openings and early seral stages offer habitat for elk, deer, black bear, grizzly bear, blue and ruffed grouse, hawks, owls, and mammalian predators such as mountain lions and bobcats and in the western extent, the endangered American peregrine falcon. The Oregon-listed endangered spotted owl has influenced the management of Douglas-fir lands in the Pacific Coast region (Salwasser 1987, Simberloff 1987). Fire suppression has favored tree regeneration at the expense of shrubs, grasses, and rapid tree growth (Arno and Gruell 1986, Gruell 1983, Wright and Bailey 1982). Under proper management, timber harvesting followed by slash burning opens up the site for range vegetation production, benefiting both wildlife and livestock (Wright and Bailey 1982).

Ponderosa Pine Ecosystem

This forest ecosystem is also widely distributed in all western regions (number 21 in fig. 2). By definition, the ponderosa pine ecosystem contains 50% or more of one of these pines: ponderosa, Jeffrey, sugar, limber, Arizona ponderosa, Apache, or Chihuahua (Garrison et al. 1977). The remaining stand composition varies by geographic region. Historical records indicate that fire kept this ecosystem open and parklike with an excellent ground cover of grasses, sedges, and forbs or with an understory of shrubs (Wright and Bailey 1982). Black bear, mule deer, elk, and mountain lion inhabit this forest type (Short 1983). This ecosystem provides timber, recreation, critical summer forage for livestock operations based at lower elevations, and prime summer range for mule deer and elk.

Fir-Spruce, Hemlock-Sitka Spruce, Western White Pine, and Larch Ecosystems

These forest ecosystems occur in the Rocky Mountains along the northern boundary of the Pacific North and Northern Rocky regions (numbers 23, 24, 22, and 25 in fig. 2). Fir-spruce forests, which also occur further south in the Northern Rocky Mountain region, generally have a dense canopy with little understory vegetation providing little forage for wild or domestic herbivores. Shrubs or forbs constitute the understory under the hemlock-sitka spruce and the western white pine ecosystem and are also found under some fir-spruce types (Eyre 1980). Larch is a seral type, succeeding to grand fir or Douglas-fir (Eyre 1980). These ecosystems are interspersed with meadows and stream bottoms with broad-leaved woody species such as aspen and willows. This mosaic of ecosystems provides habitat for moose, elk, mule deer, and white-tailed deer (Clary 1983). Other mammals include wolverine, lynx, black bear, mountain lion, coyote and, in small numbers, the grizzly bear.

Lodgepole Pine Ecosystem

Widespread over the entire western region, this ecosystem is characterized by a composition of 50% or more of lodgepole pine (number 26 in fig. 2). Understory vegetation is a function of the climatic, topographic, and edaphic characteristics of the site, and the time since the last disturbance (Bartolome 1983). Logging and fire shift understory species composition toward grasses and forbs, reducing shrubs. The 25 million acres dominated by lodgepole pine provide a significant source of forage for wild and domestic animals (Bartolome 1983). The fauna is similar to the Douglas-fir and spruce-fir ecosystems.

Redwood Ecosystem

This forest ecosystem covers a small geographic extent in California and Oregon (number 27 in fig. 2). The dense overstory of redwood (20% or more) may be in association with Douglas-fir and grand fir. Fauna include elk, mountain lion, bobcat, and black bear.

Western Hardwoods

Occurring in the Pacific Coast and Rocky Mountain regions, these forests are characterized by a stand composition of 50% or more of coast live oak, canyon live oak, blue oak, valley oak, interior live oak, or aspen. Understory vegetation is primarily grasses (number 28 in fig. 2). Fauna in the California extent include mule deer, California quail, mountain quail, skunk, and the endangered San Joaquin kit fox. Fauna in the Oregon extent is similar to the California extent, with the addition of more northerly species such as the ruffed grouse. In the Rocky Mountain extent, fauna are similar to the surrounding ecosystems. The aspen ecosystem produces significant amounts of forage in addition to valuable wood fiber in the Rocky Mountain region (Betters 1983).

GRASSLAND AND SHRUBLAND ECOSYSTEMS

Sagebrush Ecosystem

This ecosystem occupies the vast plains and plateaus derived from lava flows, ancient lake beds, and broad basins of alluvium in the Rocky Mountain, and the Pacific Coast regions (number 29 in fig. 2). This broad ecosystem type comprises several different sagebrush communities dominated by either different sagebrush species or by sagebrush and grass species (Blaisdell et al. 1982; West 1983a, 1983b). In the early years of western settlement, this type was severely impacted through grazing, cultivation, and the later abandonment of marginal farms (Blaisdell et al. 1982). Disruption of the fire cycle in the sagebrush ecosystem has led to the annualization of this type (West 1983a, 1983b). Heavy grazing pressure reduced the occurrence of the native perennial grasses, allowing sagebrush to increase. Once established, annual exotic plants such as cheatgrass provide the fine-textured fuel that allows wildfires to spread from shrub to shrub in the dry season (Young et al. 1987). The technology exists to reverse the process of annualization on sites with sufficient annual precipitation, however cheatgrass has expanded its range to include sites in the more arid margins of the Great Basin (Young et al. 1987). The sagebrush ecosystem provides habitat for game species such as sage grouse, pronghorn, and mule deer (McArthur et al. 1978) and habitat for the endangered Utah prairie dog (Garrison et al. 1977). The invasion of cheatgrass has facilitated the successful introduction of the exotic game bird, chukar partridge, which uses cheatgrass as a staple item of its diet (Leopold et al. 1981). Most wild horse herds occupy this type.

Desert Shrub and Southwestern Shrubsteppe Ecosystems

These ecosystems are found in areas of the Rocky Mountain and Pacific Coast regions (numbers 30 and 33 in fig. 2) where precipitation is usually less than 10

inches a year, and the soils are poorly developed (Stoddart et al. 1975). Generally these types are referred to as cold-desert shrublands of the temperate latitudes and hot-desert shrublands of tropical and subtropical areas. The sparse vegetation is dominated by woody plants less than 7 feet in height. Shrub species in the cold desert include shadscale, saltbush, various rabbitbrushes, greasewood, and winterfat with associated grasses and few forb species. The exotic cheatgrass has adapted to produce seed in the brief period during spring when moisture is abundant. The cold-desert shrublands furnish winter grazing for thousands of sheep and cattle (Stoddart et al. 1975) and habitat for the wildlife species such as mule deer, pronghorn, coyote, and collared peccary (Short 1983). Wild horses and burros use this ecosystem as well as the sagebrush and annual grasslands ecosystems (McArthur et al. 1978, Verner and Boss 1980). The hot-desert shrublands of California, Arizona, New Mexico, and Texas are dominated by cresotebush, mesquite, blackbrush, bursage, tarbush, paloverde, and cactus. The dominant grass species of black grama, three-awns, and tobosa are associated with side-oats grama and curly mesquite. Desert mule deer, collared peccary, antelope, desert bighorn sheep, quail, dove, and rabbit are important game species (Martin 1975). The desert tortoise, endangered in California, Nevada, and Arizona, occurs in this ecosystem (Short 1983). Hot-desert shrublands are grazed yearlong by wild and domestic herbivores. This type represents the longest history (400 years) of grazing on this continent (Stoddart et al. 1975). The geographic region within which the ecosystems of southwestern shrubsteppe, desert shrub, desert grassland occur are drained by numerous rivers and streams. Riparian vegetation along these waterways has undergone severe manipulation from water developments, overgrazing, and invasion of exotics such as saltcedar (Swift 1984).

Shinnery Ecosystem

This ecosystem forms a narrow corridor on the sand hills and river dunes along the Canadian River in Texas (number 31 in fig. 2). This midgrass prairie is associated with open to dense stands of broad-leaved deciduous shrubs, primarily shin oak, and occasionally needle-leaved low trees and shrubs. Grass species include little bluestem and side-oats grama, with occasional sand bluestem. Fauna reflect the surrounding ecosystems of plains grasslands, pinyon-juniper, and southwestern shrubsteppe.

Texas Savanna Ecosystem

This high shrub savanna ecosystem varies from dense to open canopies of broad-leaved, deciduous and evergreen low trees and shrubs, and needle-leaved evergreen low trees and shrubs (number 32 in fig. 2). The understory component is short-grass and mid-grass species, including bluestems, three-awns, buffalo grass, gramas, curly mesquite, and tobosa. Mesquite is the dominant shrub, although other shrubs include acacia, live oak, juniper, and ceniza shrub. This ecosystem is noted for the abundance of white-tailed deer, wild turkey (Garrison et al. 1977), and collared peccary (Schmidt and Gilbert 1978). Fox squirrel, ringtail, raccoon, mourning dove, scaled quail, and bobwhite also inhabit this ecosystem.

Chaparral-Mountain Shrub Ecosystem

This ecosystem varies across the Pacific Coast and Rocky Mountain regions within which it occurs (number 34 in fig. 2). The California chaparral is characterized by little summer rainfall and comparatively heavy winter precipitation. Although this ecosystem's chief value is watershed protection, livestock do obtain some forage from the chaparral (Stoddart et al. 1975). Part of the critical habitat for the California condor, now found only in captivity, is within this type. Large portions of this ecosystem have been converted to annual grasslands. In the Rocky Mountain foothills, this type exists as open savannas or dense stands of scrub oak. Found in scattered areas in Utah, Arizona, New Mexico, and Colorado, the mountain brush type occurs as a discontinuous transition zone between coniferous forest and grassland or sagebrush ecosystems. This type is not dominated by a single shrub species but rather the shrubs of serviceberry, ceanothus, and snowberry form open stands under which grasses provide suitable forage for livestock (Stoddart et al. 1975).

Pinyon-Juniper Ecosystem

This type, often adjacent to sagebrush, occupies the eroded and rough dissections of western basins and mountains in all of the western regions (number 35 in fig. 2). Pinyon pine and juniper occur as dense to open woodland and savanna woodland. These tree species may grow to 30 feet tall, but commonly are under 15 feet. Understory vegetation appears to be related to climatic patterns where in the cold winter and dry summer regimes, cool season grasses are found; in dry winter climates, warm season grasses occur; and with moist cool winters, chapparal understories are associated with this type. Livestock grazing has been an important use in this type where forage production may be as much as 600 pounds per acre in open stands. Livestock grazing is usually low-intensity, season-long or year-long (Clary 1987). Although past heavy grazing and the increased tree overstory have reduced the forage production available within this type, prescribed fire can be used to reestablish understory species (Everett 1987). Fauna include mule deer, mountain lion, coyote, bobcat, jackrabbit, and numerous species of birds. Commercial products from the pinyon-juniper woodlands are in greater demand today than 10 years ago (Spang 1987). The multiple use management of this ecosystem includes fuelwood, pine nuts, forage, wildlife habitat,

watershed protection, recreational opportunities, esthetic values, wilderness, and energy and mining activities (Spang 1987, Wagstaff 1987).

Mountain Grassland Ecosystem

Dominated by fescue and wheatgrass bunchgrasses, these grasslands are open untimbered areas surrounded by ponderosa pine, Douglas-fir, or lodgepole pine ecosystems (number 36 in fig. 2). The encroachment of trees is slow because of several factors including strong competition for moisture from the bunchgrasses, low temperatures, and soil heaving (Paulsen 1975). Fauna reflect the surrounding ecosystems. Livestock began grazing these grasslands at higher elevations in Colorado, Wyoming, and Montana over 100 years ago, and by 1900 most were overgrazed. Current use is less than 25% of the former high levels (Paulsen 1975). These grasslands are still important summer ranges for cattle and wildlife, have significance as watersheds for water delivery downstream, and are important recreation areas. Although considered originally part of the mountain grasslands (Garrison et al. 1977), the Palouse prairie is described as an intermountain-bunchgrass type by Stoddart et al. (1975). Unlike the mountain grasslands, the Palouse is a grassland not subject to invasion by trees. As a reflection of the deep soil high in organic matter, much of the Palouse Prairie in Oregon, Washington, and Idaho was plowed for production of small grains (Garrison et al. 1977).

Mountain Meadow Ecosystem

Wet to intermittently wet open sites within the forested zones in western mountains characterize this ecosystem (number 37 in fig. 2). Grasses, sedges, and rushes dominate, and fauna reflect the surrounding ecosystems. This type serves as a source of water, highly productive forage for big game such as mule deer, and elk (Turner and Paulsen 1976), forage for livestock, and recreational activities.

Plains Grassland Ecosystem

The short warm-season grasses of blue grama and buffalo grass dominate this ecosystem found in the Rocky Mountain region (number 38 in fig. 2). These grasses coexist with a minor component of forbs, and shrubs such as juniper, sagebrush, silver buffaloberry, skunkbush sumac, rabbitbrush, and mesquite. Two environmental gradients determine species composition within this type. The temperature gradient increases from north to south and the moisture gradient increases from west to east (Stoddart et al. 1975). Pronghorn, mule deer, white-tailed deer, and white-tailed and black-tailed jackrabbit grazed this vegetation type, while prairie dogs and a variety of small rodents provide food for coyotes and raptors. The greater prairie chicken, and sharptailed grouse are important game species. Grasshoppers annually consume 21 to 23% of available range vegetation (Hewitt and Onsager 1983) and at epidemic levels, can present considerable damage to the forage base. The long-billed curlew was once widely distributed across this region, and its decline has been associated with decreasing short-grass prairie habitat (Kantrud 1982). Although the primary economic use of this ecosystem is livestock grazing, agriculture also has an impact. The conversion of native grassland to cropland, called sodbusting, reached high levels during the late 1970s when a poor livestock economy was coupled with a relatively good grain market (Heimlich 1985, Huszar and Young 1984). This extensive land conversion provided much of the incentive for conservation provisions in the Food Security Act of 1985 (Joyce and Skold 1988). Within the plains grasslands and the prairie ecosystems, major river systems are vegetated by riparian communities such as elm-ash-cottonwood or oak-hickory ecosystems. The relative lack of forest vegetation on the plains makes these riparian communities important to wildlife (Swift 1984). Channelizations of streams, and agricultural developments have significantly reduced the original area of these riparian ecosystems (Swift 1984).

Prairie Ecosystem

This ecosystem (number 39 in fig. 2) is known as the true prairie (Risser et al. 1981). Bluestem grasses dominate and woody vegetation is rare. Some forbs occur. Fauna is similar to the plains grasslands ecosystem. The northern extent of this type, known as the prairie pothole region, is an important breeding ground for migratory waterfowl. Shelterbelt plantings have increased the habitat for birds such as mourning doves. Because of the high soil fertility, much of this type has been converted to cropland. The eastern interface of this ecosystem with the eastern deciduous forests results in a mixing of grasses, shrubs, and some trees in this type. Fire and goats have been used to suppress shrub and tree invasion into the prairie (Wright and Bailey 1982).

Desert Grassland Ecosystem

Blue and black grama, galleta, tobosa, curly mesquite, and several threeawn species are the dominant grasses of this southwestern ecosystem (number 40 in fig. 2). Other grass species vary with the moisture regime of a site. Shrubs, such as creosotebush, burroweed, cactus, and mesquite, have been associated with this type, however, extensive shrub invasion of grasslands has become a widespread phenomenon over the past 100 years (Pieper et al. 1983). Five factors were suggested for the invasion: increased livestock grazing, climatic change, increased competition among plant species, rabbits and rodents, and fire control. Pronghorn, collared peccary, and mourning dove inhabit this ecosystem (Short 1983). Grasshoppers and harvester ants can cause

considerable damage to desert grassland vegetation (Pieper et al. 1983).

Wet Grassland Ecosystem

This diverse type occurs as the wet prairies and marshes along the eastern coast, the Florida Everglades and palmetto prairie, the tule marshes in central California, and the wet grasslands on the floodplains in the Intermountain plateaus (number 41 in fig. 2). Cordgrass, saltgrass, and a few forbs form the coastal grassland ecosystem. Scattered shrubs and low to medium tall trees form the overstory with an understory of wiregrass and saw-palmetto in the palmetto grassland, or sawgrass and three-awn in the Everglades. Tules, other bulrushes, and sedges dominate the landscape in the wet marshes in the intermountain floodplains. Fauna in wet grasslands are as diverse as the grasslands. The Central Valley of California and the coastal marshes of Texas and Louisiana are important habitat for seasonal migrations of waterfowl, including the endangered whooping crane. Klopatek et al. (1979) estimated that by 1974, tule marshes had lost 89% of their original area, the Everglades had been reduced 57%, and the palmetto prairie, 27%. Losses were primarily the result of land conversion to cropland.

Annual Grassland Ecosystem

Introduced annual grasses dominate the vegetation, although forbs and perennial bunchgrasses can also be found in this ecosystem which extends from California north into Oregon (number 42 in fig. 2). Fauna includes mule deer, California quail, and numerous small mammals. Mourning dove is also an important species here (Verner and Boss 1980). Much of this type at lower elevations has been converted to irrigated agricultural land. At higher elevations, use is mainly livestock grazing, some dry farming and, because of the proximity to large metropolitan areas in California, intensive recreational use (California Department of Forestry 1987).

Alpine Ecosystem

This type occurs above timberline in the Rocky Mountain and Pacific Mountain systems (number 43 in fig. 2). Grasses, grasslike species, and forbs predominate. The particular composition reflects the environment of the site which can vary dramatically depending on wind and water stress. Wind swept, highly erosive, dry slopes may have cushion plant communities, whereas depressions in the landscape may form a wet meadow. Lakes and ponds with endemic trout can be found within the type, although many lakes have been stocked with introduced species (Thilenius 1975). Year-round mammals include pika, pocket gopher, and yellow-bellied marmot. An important game bird is the ptarmigan. Mule deer, elk, and mountain sheep use the ecosystem for summer forage. Traditionally, large bands of domestic sheep used this ecosystem in summer. This practice has diminished in use, mainly because of the decline in the range sheep industry. Recreational use consists of hiking, hunting, and fishing during the summer, and skiing during the winter (Thilenius 1975).

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APPENDIX C: ENDANGERED (E) AND THREATENED (T) PLANTS AND THEIR DISTRIBUTION WITHIN THEUNITED STATES AND TERRITORIES.

Species				
Scientific name	Common name	Range	Status	Year listed
Agavaceae-Agave family:				
Agave arizonica	Arizona agave	AZ	E	1984
Aizoaceae-Ice plant family:				
Geocarpon minimum	None	AR, MO	T	1987
Alismataceae-Water-plantain family:				
Sagittaria fasciculata	Bunched arrowhead	NC, SC	E	1979
Amaranthaceae-Amaranth family:				
Achyranthes rotundata	None	HI	E	1986
Annonaceae-Custard-apple family:				
Asimina tetramera	Four-petal pawpaw	FL	E	1986
Deeringothamnus pulchellus	Beautiful pawpaw	FL	E	1986
Deeringothamnus rugelii	Rugel's pawpaw	FL	E	1986
Apiaceae-Parsley family:				
Eryngium constancei	Loch Lomond coyote-thistle	CA	E	1986
Eryngium cuneifolium	Snakeroot	FL	E	1987
Oxypolis canbyi	Canby's dropwort	DE, GA, MD, NC, SC	E	1986
Apocynaceae-Dogbane family:				
Cycladenia humilis var. jonesii	Jones cycladenia	AZ, UT	T	1986
Aquifoliaceae-Holly family:				
Ilex cookii	Cook's holly	Puerto Rico	E	1987
Asclepiadaceae-Milkweed family:				
Asclepias welshii	Welsh's milkweed	UT	T	1987
Aspleniaceae:				
Polystichum aleuticum	Aleutian shield-fern	AK	E	1988
Asteraceae-Aster family:				
Argyroxiphium sandwicense ssp. sandwicense	'Ahinahina (Muana Kea silversword)	HI	E	1986
Bidens cuneata	Cuneate bidens	HI	E	1984
Chrysopsis floridana (= Heterotheca floridana)	Florida golden aster	FL	E	1986
Cirsium vinaceum	Sacramento Mountains thistle	NM	T	1987
Dyssodia tephroleuca	Ashy dogweed	TX	E	1984
Echinacea tennesseensis	Tennessee purple coneflower	TN	E	1979
Enceliopsis nudicaulis var. corrugata	Ash Meadows sunray	NV	T	1985
Erigeron maguirei var. maguirei	Maguire daisy	UT	E	1985
Erigeron rhizomatus	Rhizome fleabane	NM	T	1985
Grindelia fraxinopratensis	Ash Meadows gumplant	CA, NV	T	1985
Hymenoxys acaulis var. glabra	Lakeside daisy	OH	T	1988
Hymenoxys texana	None	TX	E	1986
Liatris helleri	Heller's blazing star	NC	T	1987
Lipochaeta venosa	None	HI	E	1979
Pityopsis ruthii (= Heterotheca ruthii, = Chrysopsis ruthii)	Ruth's golden aster	TN	E	1985
Senecio franciscanus	San Francisco Peaks groundsel	AZ	T	1983
Solidago albopilosa	White-haired goldenrod	KY	T	1988
Solidago shortii	Short's goldenrod	KY	E	1985
Solidago spithamaea	Blue Ridge goldenrod	NC, TN	T	1985
Stephanomeria malheurensis	Malheur wire-lettuce	OR	E	1982
Townsendia aprica	Last Chance townsendia	UT	T	1985
Berberidaceae-Barberry family:				
Mahonia sonnei (= Berberis s.)	Truckee barberry	CA	E	1979
Betulaceae-Birch family:				
Betula uber	Virginia round leaf-birch	VA	E	1978
Bignoniaceae-Bignonia family:				
Crescentia portoricensis	Higuero de Sierra	Puerto Rico	E	1987

Species				
Scientific name	Common name	Range	Status	Year listed
Boraginaceae-Borage family:				
Amsinckia grandiflora	Large-flowered fiddleneck	CA	E	1985
Brassicaceae-Mustard family:				
Arabis mcdonaldiana	McDonald's rock-cress	CA	E	1978
Erysimum capitatum var. angustatum	Contra Costa wallflower	CA	E	1978
Glaucocarpum suffrutescens	Toad-flax cress	UT	E	1987
Lesquerella filiformis	Missouri bladderpod	MO	E	1987
Lesquerella pallida	White bladderpod	TX	E	1987
Thelypodium stenopetalum	Slender-petaled mustard	CA	E	1984
Warea carteri	Carter's mustard	FL	E	1987
Warea amplexifolia	Wide-leaf warea	FL	E	1987
Buxaceae-Boxwood family:				
Buxus vahlii	Vahl's boxwood	Puerto Rico	E	1985
Cactaceae-Cactus family:				
Ancistrocactus tobuschii (= Echinocactus t., Mammillaria t.)	Tobusch fishhook cactus	TX	E	1979
Cereus eriophorus var. fragrans	Fragrant prickly-apple	FL	E	1985
Cereus robinii	Key tree-cactus	FL	E	1984
Coryphantha minima (= C. nellieae, Escobaria n., Mammillaria n.)	Nellie cory cactus	TX	E	1979
Coryphantha ramillosa	Bunched cory cactus	TX	T	1979
Coryphantha robbinsorum (= Cochiseia r., Escobaria r.)	Cochise pincushion cactus	AZ	T	1986
Coryphantha sneedii var. leei (= Escobaria l., Mammillaria l.)	Lee pincushion cactus	NM	T	1979
Coryphantha sneedii var. sneedii (= Escobaria s., Mammillaria s.).	Sneed pincushion cactus	TX, NM	E	1979
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's head cactus	AZ	E	1979
Echinocereus engelmannii var. purpureus	Purple-spined hedgehog cactus	UT	E	1979
Echinocereus fendleri var. kuenzleri (= E. kuenzleri, E. hempelii of authors, not Fobe)	Kuenzler hedgehog cactus	NM	E	1979
Echinocereus lloydii (= E. roetteri var. l.)	Lloyd's hedgehog cactus	TX	E	1979
Echinocereus reichenbachii var. albertii (= E. melanocentrus)	Black lace cactus	TX	E	1979
Echinocereus triglochidiatus var. arizonicus (= E. arizonicus)	Arizona hedgehog cactus	AZ	E	1979
Echinocereus triglochidiatus var. inermis (= E. coccineus var. i., E. phoeniceus var. i.)	Spineless hedgehog cactus	CO, UT	E	1979
Echinocereus viridiflorus var. davisii (= E. davisii)	Davis' green pitaya	TX	E	1979
Neolloydia mariposensis (= Echinocactus m., Echinomastus m.)	Lloyd's Mariposa cactus	TX	T	1979
Pediocactus bradyi (= Toumeya b.)	Brady pincushion cactus	AZ	E	1979
Pediocactus despainii	San Rafael cactus	UT	E	1987
Pediocactus knowltonii (= P. bradyi var. k. Toumeya k.)	Knowlton cactus	NM, CO	E	1979
Pediocactus peeblesianus var. peeblesianus (= Echinocactus p., Navajoa p., Toumeya p., Utahia p.)	Peebles Navaho cactus	AZ	E	1979
Pediocactus sileri (= Echinocactus s., Utahia s.)	Siler pincushion cactus	AZ, UT	E	1979
Sclerocactus glaucus (= Echinocactus g., E. subglaucus, E. whipplei var. g., Pediocactus g., S. franklinii, S. whipplei var. g.)	Uinta Basin hookless cactus	CO, UT	T	1979
Sclerocactus mesae verdae (= Coloradoa m., Echinocactus m., Pediocactus m.)	Mesa Verde cactus	CO, NM	T	1979
Sclerocactus wrightiae (= Pediocactus w.)	Wright fishhook cactus	UT	E	1979
Caryophyllaceae-Pink family:				
Arenaria cumberlandensis	Cumberland sandwort	TN, KY	E	1988
Paronychia chartacea (= Nyachia pulvinata)	Papery whitlow-wort	FL	T	1987
Schiedea adamantis	Diamond Head schiedea	HI	E	1984
Chenopodiacea-Goosefoot family:				
Nitrophila mohavensis	Amargosa niterwort	CA	E	1985
Cistaceae-Rockrose family:				
Hudsonia montana	Mountain golden heather	NC	T	1980
Convolvulaceae-Morning glory family:				
Bonamia grandiflora	Florida bonamia	FL	T	1987

Species				
Scientific name	Common name	Range	Status	Year listed
Crassulaceae-Stonecrop family:				
Dudleya traskiae	Santa Barbara Island liveforever	CA	E	1978
Cucurbitaceae-Gourd family:				
Tumamoca macdougalii	Tumamoc globe-berry	AZ	E	1986
Cupressaceae-Cypress family:				
Cupressus abramsiana	Santa Cruz cypress	CA	E	1987
Cyatheaceae-Tree ferm family:				
Cyathea dryopteroides	Elfin tree fern	Puerto Rico	E	1987
Cyperaceae-Sedge family:				
Carex specuicola	None	AZ	T	1985
Ericaceae-Heath family:				
Arctostaphylos pungens var. ravenii (= A. hookeri ssp. ravenii)	Presidio (= Raven's) manzanita	CA	E	1979
Rhododendron chapmanii	Chapman rhododendron	FL	E	1979
Euphorbiaceae-Spurge family:				
Euphorbia (= Chamaesyce) deltoidea ssp. deltoidea	Spurge	FL	E	1985
Euphorbia (= Chamaesyce) garberi	None	FL	T	1985
Euphorbia skottsbergii var. kalaeloana	Ewa Plains 'akoko	HI	E	1982
Fabaceae-Pea family:				
Amorpha crenulata	Crenulate lead-plant	FL	E	1985
Astragalus humillimus	Mancos milk-vetch	CO, NM	E	1985
Astragalus montii	Heliotrope milk-vetch	UT	T	1987
Astragalus perianus	Rydberg milk-vetch	UT	T	1978
Astragalus phoenix	Ash Meadows milk-vetch	NV	T	1985
Astragalus robbinsii var. jesupi	Jesup's milk-vetch	VT, NH	E	1987
Baptisia arachnifera	Hairy rattleweed	GA	E	1978
Galactia smallii	Small's milkpea	FL	E	1985
Hoffmannseggia tenella	Slender rush-pea	TX	E	1985
Lespedeza leptostachya	Prairie bush-clover	IA, IL, MN, WI	T	1987
Lotus dendroideus ssp. traskiae (= L. scoparius ssp. t.)	San Clemente Island broom	CA	E	1977
Lupinus aridorum	Scrub lupine	FL	E	1987
Mezoneuron kavaiense	Uhiuhi	HI	E	1986
Serianthes nelsonii	Hayun lagu (Guam) Tronkon guafi (Rota)	Guam Rota	E	1987
Trifolium stoloniferum	Running buffalo clover	WV, KY, IN	E	1987
Vicia menziesii	Hawaiian vetch	HI	E	1978
Flacourtiaceae-Flacourtia family:				
Banara vanderbiltii	Palo de Ramon	Puerto Rico	E	1987
Frankeniaceae-Frankenia family:				
Frankenia johnstonii	Johnston's frankenia	TX	E	1984
Gentianaceae-Gentian family:				
Centaurium namophilum	Spring-loving centaury	CA, NV	T	1985
Goodeniaceae-Goodenia family:				
Scaevola coriacea	Dwarf naupaka	HI	E	1986
Hydrophyllaceae-Waterleaf family:				
Phacelia argillacea	Clay phacelia	UT	E	1978
Phacelia formosula	North Park phacelia	CO	E	1982
Hypericaceae-St. Johns-Wort Family:				
Hypericum cumulicola	Highlands scrub hypericum	FL	E	1987
Isoetaceae-Quillwort family:				
Isoetes melanospora	Black-spored quillwort	GA, AL, SC	E	1988
I. tegetiformans	Mat-forming quillwort	GA, AL, SC	E	1988
Lamiaceae-Mint family:				
Acanthomintha obovata ssp. duttonii	San Mateo thornmint	CA	E	1985
Dicerandra cornutissima	Longspurred mint	FL	E	1985
Dicerandra frutescens	Scrub mint	FL	E	1985
Dicerandra immaculata	Lakela's mint	FL	E	1985
Haplostachys haplostachya var. angustifolia	None	HI	E	1979
Hedeoma apiculatum	McKittrick pennyroyal	TX, NM	T	1982
Hedeoma todsenii	Todsen's pennyroyal	NM	E	1981
Pogogyne abramsii	San Diego mesa mint	CA	E	1978

Species				
Scientific name	Common name	Range	Status	Year listed
Scutellaria montana	Large-flowered skullcap	GA, TN	E	1986
Stenogyne angustifolia var. angustifolia	None	HI	E	1979
Lauraceae-Laurel family:				
Lindera melissifolia	Pondberry	AL, AR, FL, GA, LA, MO, MS, NC, SC	E	1986
Liliaceae-Lily family:				
Erythronium propullans	Minnesota trout lily	MN	E	1986
Harperocallis flava	Harper's beauty	FL	E	1979
Trillium persistens	Persistent trillium	GA, SC	E	1978
Trillium reliquum	Relict trillium	AL, SC, GA	E	1988
Loasaceae-Loasa family:				
Mentzelia leucophylla	Ash Meadows blazing star	NV	T	1985
Lythraceae-Loosestrife family:				
Lysimachia aspervlaefolia	Rough-leaved loosestrife	NC, SC	E	1987
Maalvaceae-Mallow family:				
Abutilon menziesii	Ko'oloa'ula	HI	E	1986
Callirhoe scabriuscula	Texas poppy-mallow	TX	E	1981
Hibiscadelphus distans	Kauai hau kuahiwi	HI	E	1986
Iliamna corei	Peter's Mountain mallow	VA	E	1986
Kokia cookei	Cooke's kokio	HI	E	1979
Kokia drynarioides	Koki'o (= hau hele'ula or Hawaii tree cotton)	HI	E	1984
Malacothamnus clementinus	San Clemente Island bush-mallow	CA	E	1977
Sidalcea pedata	Pedate checker-mallow	CA	E	1984
Meliaceae-Mahogany family:				
Trichilia triacantha	Baricao	Puerto Rico	E	1988
Nyctaginaceae-Four-o'clock family:				
Mirabilis macfarianei	MacFarlane's four-o'clock	ID, OR	E	1979
Oleaceae-Olive family:				
Chionanthus pygmaeus	Pygmy fringe tree	FL	E	1987
Onagraceae-Evening-primrose family:				
Camissonia benitensis	San Benito evening-primrose	CA	T	1985
Oenothera avita ssp. eurekensis	Eureka Valley evening-primrose	CA	E	1978
Oenothera deltoides ssp. howellii	Antioch Dunes evening-primrose	CA	E	1978
Orchidaceae-Orchid family:				
Isotria medeoloides	Small whorled pogonia	CT, IL, MA, MD, ME, MI, MO, NC, NH, NJ, NY, PA, RI, SC, VA, VT	E	1982
Spiranthes parksii	Navasota ladies'-tresses	TX	E	1982
Papaveraceae-Poppy family:				
Arctomecon humilis	Dwarf bear-poppy	UT	E	1979
Piperaceae-Pepper family:				
Peperomia wheeleri	Wheeler's peperomia	Puerto Rico	E	1987
Poaceae-Grass family:				
Tuctoria mucronata (= Orcuttia m.)	Solano grass	CA	E	1978
Panicum carteri	Carter's panicgrass	HI	E	1983
Swallenia alexandrae	Eureka Dune grass	CA	E	1978
Zizania texana	Texas wild-rice	TX	E	1978
Polemoniacacea-Phlox family:				
Eriastrom densifolium	Santa Ana wooly-star	CA	E	1987
Polygalaceae-Milkwort family:				
Polygala smallii	Tiny polygala	FL	E	1985
Polygonaceae-Buckwheat family:				
Centrostegia leptoceras	Slender-horned spineflower	CA	E	1987
Eriogonum gypsophilum	Gypsum wild-buckwheat	NM	T	1981
Eriogonum ovalifolium var. williamsiae	Steamboat buckwheat	NV	E	1986
Eriogonum pelinophilum	Clay-loving wild-buckwheat	CO	E	1984
Polygonella basiramia (= Polygonella ciliata var. basiramia)	Wireweed	FL	E	1987

Species				
Scientific name	Common name	Range	Status	Year listed
Primulaceae-Primrose family:				
Primula maguirei	Maguire primrose	UT	T	1985
Ranunculaceae-Buttercup family:				
Aconitum noveboracense	Northern wild monkshood	IA, NY, OH, WI	T	1978
Clematis socialis	Alabama leather flower	AL	E	1986
Delphinium kinkiense	San Clemente Island larkspur	CA	E	1977
Rhamnaceae-Buckthorn family:				
Gouania hillebrandii	None	HI	E	1984
Rosaceae-Rose family:				
Cowania subintegra	Arizona cliffrose	AZ	E	1984
Ivesia eremica	Ash Meadows ivesia	NV	T	1985
Potentilla robbinsiana	Robbins' cinquefoil	NH, VT	E	1980
Prunus geniculata	Scrub plum	FL	E	1987
Rubiaceae-Coffee family:				
Gardenia brighamii	Na'u (Hawaiian gardenia)	HI	E	1985
Rutaceae-Citrus family:				
Zanthoxylum thomasianum	St. Thomas prickly-ash	Puerto Rico, Virgin Islands	E	1985
Santalaceae-Sandalwood family:				
Santalum freycinethianum var. lanaiense	Lanai sandalwood or 'iliahi	HI	E	1986
Sarraceniaceae-Pitcher plant family:				
Sarracenia oreophila	Green pitcher plant	AL, GA, TN	E	1980
Saxifragaceae-Saxifrage family:				
Ribes echinellum	Miccosukee gooseberry	FL, SC	T	1985
Scrophulariaceae-Snapdragon family:				
Amphianthus pusillus	Little amphianthus	GA, AL, SC	T	1988
Castilleja grisea	San Clemente Island Indian paintbrush	CA	E	1977
Cordylanthus maritimus ssp. maritimus	Salt marsh bird's-beak	CA	E	1978
Cordylanthus palmatus	Palmate-bracted bird's-beak	CA	E	1986
Pedicularis furbishiae	Furbish lousewort	ME	E	1978
Penstemon haydenii	Blowout penstemon	NE	E	1987
Solanaceae-Nightshade family:				
Goetzea elegans	Beautiful goetzea, matabuey	Puerto Rico	E	1985
Styracaceae-Styrax family:				
Styrax texana	Texas snowbells	TX	E	1984
Taxaceae-Yew family:				
Torreya taxifolia	Florida torreya	FL, GA	E	1984
Thymelaeaceae:				
Daphnopsis hellerana	None	Puerto Rico	E	1988
Verbenaceae - Verbena family:				
Cornutia obovata	Palo de Nigua	Puerto Rico	E	1988

Source: U.S. *Department of Interior, Fish and Wildlife Service* (1987, 1988), *Endangered Species Technical Bulletin, Vol. 12, 13* (thru July 1988).

APPENDIX D: GLOSSARY

Sources for these definitions are listed at the end of the glossary.

Allelopathy.—Chemical inhibition of plants, through products of metabolism, upon each other.

Allotment.—An area designated for the use of a prescribed number and kind of livestock under one plan of management. May be federal or any combination of federal and private ownerships. May consist of several or only one pasture.

Allotment Management Plan (AMP).—The program of action designated to reach a given set of objectives for a given allotment on public lands. It is prepared and agreed to by the permittee(s) and appropriate agency and prescribes the livestock operations, range improvement practices, and maintenance.

Anadromous.—Migrating from the sea up a river to spawn; example, salmon.

Animal Unit (AU).—One mature cow of approximately 1,000 pounds and its calf, or equivalent. Conversion factors have been developed to equate other animal types to this animal unit.

Animal Unit Month (AUM).—Amount of forage required to sustain one animal unit (AU) for 1 month.

Aquifer.—A geologic formation capable of transmitting water through its pores at a rate sufficient for water supply purposes. Aquifers are usually saturated sands, gravel, fractures, caverns, or vesicular rock.

Arid.—A term applied to regions or climates where lack of sufficient moisture severely limits growth and production of vegetation. Limits of precipitation vary considerably according to temperature conditions, with an upper annual limit for cool regions of 10 inches or less and for tropical regions, 15 to 20 inches.

Assessment regions.—Regions used in this and other technical supporting documents and in the assessment document. See California, Northern, Northern Rocky, Pacific Coast, Pacific North, Rocky Mountain, Southern, and Southwest.

AUM.—See Animal Unit Month.

Biological control.—The control of parasites, plants, or other pests by the introduction, preservation, or facilitation of natural predators, parasites, or other enemies, by sterilization techniques, by the use of inhibitory hormones, or by other biological means.

Biotechnology.—Broadly defined, includes any technique that uses living organisms or processes to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses.

Boxed beef.—Cattle carcasses cut into small portions and boxed at the packing plant. Packing houses previously sold the retailer half or quarter carcasses of beef.

Breeding herd.—The animals retained for breeding purposes to provide for the perpetuation of the herd or band. Excludes animals being prepared for market.

Browse.—That part of leaf and twig growth of shrubs, woody vines, and trees available for animal consumption. Also the act of consuming browse.

California Region.—Assessment region encompassing the state of California. This is the National Forest System Region 5.

Carcass weight.—Weight of slaughtered animal after offal (inedible parts) are removed.

Carrying capacity.—The maximum stocking rate possible without inducing damage to vegetation or related resources. It may vary from year to year on the same area because of fluctuating forage production.

Cattle cycle.—A period of approximately 10 years in which the number of beef cattle is expanded for several consecutive years and then reduced for several years in response to perceived changes in profitability of beef production.

Channelization.—The process of excavating a waterway; straightening a streambed so that water flows more efficiently through an area.

Chaparral.—A shrub community composed of sclerophyllous species.

Climax.—The final or stable biotic community in a successional series which is self perpetuating and in dynamic equilibrium with the physical habitat, the assumed end point in secondary succession.

Cold deserts.—The Intermountain area or Great Basin Desert of North America, usually over 60% of its precipitation is in the form of snow.

Concentrate feed.—Grains or their products and other processed food materials that contain a high proportion of nutrients and are low in fiber and water.

Conservation compliance.—A provision of the 1985 Food Security Act that denies future commodity program benefits to producers who do not have specific conservation plans on highly erodible croplands now in production.

Conservation Reserve Program (CRP).—A provision of the 1985 Food Security Act that pays farmers to convert highly erodible cropland to permanent cover of grasses, shrubs, or trees, and to keep that land in permanent cover for 10 years. The land cannot be grazed by livestock or harvested for commercial purposes.

Constant dollars.—Dollars expressed in terms of purchasing power using a particular year as the standard of comparison, adjusted for inflation or deflation using a national index, such as the GNP index (Gross National Product).

Cool-season grasses.—A grass which generally makes the major portion of its growth during the late fall, winter, and early spring. Cool season plants generally exhibit the C-3 photosynthetic pathway, that is, the pentose phosphate pathway of carbon dioxide assimilation.

Coordinated Resource Management Planning (CRMP).—The process whereby various user groups are involved in discussion of alternative resource uses and collectively diagnose management problems, establish goals and objectives, and evaluate multiple use resource management.

Crop residue.—Plant material available for grazing on land from which a crop has been harvested.

Cropland.—Land under cultivation within the last 24 months including cropland harvested, crop failures, cultivated summer fallow, idle cropland used only for pasture, orchards, and land in soil improving crops, but excluding land cultivated in pasture.

CRP.—See Conservation Reserve Program.

Deeded nonirrigated grazing land.—Land owned as a part of the livestock enterprise that is not irrigated.

Defoliation.—The removal of plant leaves, i.e., by grazing or browsing, cutting, chemical defoliant, or natural phenomena such as hail, fire, or frost.

Demand.—The quantity of product willingly bought per unit of time at a specific price.

Desertification.—The process by which an area or region becomes more arid through loss of soil and vegetative cover.

Disposable personal income.—The amount of income available for spending.

Ecological status.—The present state of vegetation and soil protection of an ecological site in relation to the potential natural community for the site. Vegetation status is the expression of the relative degree to which the kinds, proportions, and amounts of plants in a community resemble that of the potential natural community. If classes are used, they should be described in ecological rather than utilization terms. Soil status is a measure of present vegetation and litter cover relative to the amount of cover needed on the site to prevent accelerated erosion.

Edible weight.—This weight measure excludes all bones, but includes the 1/4- to 1/2-inch of separable fat normally sold on retail cuts of meat such as beef, veal, pork, lamb, and mutton.

Endemic.—Local; native; indigenous.

Ephemeral.—Lasting a very short time; transitory.

Exotic.—An organism or species which is not native to where it is found.

Fed animals.—Livestock, usually cattle, in a feedlot.

Fed beef production.—Feeding of grain and other concentrate feedstuffs to produce slaughter cattle.

Feedlot.—A large plot of land where livestock are fed and fattened before slaughter.

Feral.—Escaped from cultivation or domestication and existing in the wild.

Forage.—Browse and herbage which is available and may provide food for grazing animals or be harvested for feeding.

Forb.—Any broad leafed herbaceous plant other than grasses, sedges, or rushes.

Forest land.—Land that is at least 10% stocked by forest trees of any size, including land that formerly had such a tree cover and that will be naturally or artificially regenerated. Forest land includes areas between heavily forested and nonforested lands that are at least 10% stocked with forest trees. Forest land includes pinyon juniper and chaparral areas in the West.

Grazed roughages.—Forage harvested by grazing or browsing forest, range, or pastureland. Roughages are plant materials containing a low proportion of nutrients per unit of weight and usually bulky and coarse, high in fiber, and low in total digestible nutrients.

Grazinglands.—A collective term that includes all lands having plants harvestable by grazing without reference to land tenure, other land uses, management, or treatment practices. Grazinglands include rangelands, transitory range, and forest lands which are suitable for grazing.

Grazing lease.—A document authorizing use of the public lands for the purpose of grazing livestock.

Habitat.—Place where an animals finds the required arrangement of food, cover, and water to meet its biological needs.

Hardwoods.—Dicotyledonous trees, usually broad-leaved and deciduous.

Harvested forages.—Forage mechanically harvested from pasturelands or haylands.

Heifer.—A cow that has not produced a calf and is under 3 years of age.

Herbaceous.—Vegetative growth with little or no woody component.

Herbage.—The above-ground biomass of herbaceous plants regardless of grazing preference or availability.

Herbicide.—Any chemical which is toxic to plants.

Herbivore.—Animals that subsist principally or entirely on plants or plant materials. Herbivores include domestic and wild grazers.

Human-related land use.—Areas within the legal boundaries of cities and towns; suburban areas developed for residential, industrial, or recreational purposes; school yards; roads; railroads; airports; beaches; rights-of-way; or other nonforest land not included in any other specified land use class.

Joint production.—Multiple outputs, such as wildlife and livestock, produced by combining multiple inputs, or management practices.

Multispecies grazing.—One species following another through the grazing area or two or more species grazing the area in combination.

National Forest System.—A branch of USDA Forest Service that manages and protects 191 million acres of land, including 32 million acres of wilderness.

National Grasslands.—Lands administered by the Forest Service but are excluded from the definition of rangelands in the Public Rangelands Improvement Act of 1978.

Nominal price.—Price including the real opportunity cost and inflation.

Non-use.—An authorization to refrain from grazing livestock without loss of preference for further consideration.

Northern Region.—Assessment region encompassing the states of Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio, West Virginia, Pennsylvania, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine. This is National Forest System Region 9.

Northern Rocky Region.—Assessment region encompassing the states of Idaho, Montana, North Dakota, Wyoming, South Dakota, Nebraska, Kansas, Colorado, Utah, and Nevada. This is National Forest System Regions 1, 2, and 4.

Noxious.—Harmful or injurious to health or physical well-being; with the passage of the Noxious Weed Act, the term "noxious weed" has become a legal term referring only to those species designated by the Secretary of Agriculture as noxious weeds.

Oregon Range Evaluation Project (EVAL).—A test case in multiresource planning coordinated by numerous state and federal agencies.

Ornamental.—A plant cultivated for decorative purposes.

Pacific Coast Region.—Assessment region combining the Pacific North and California assessment regions.

Pacific North Region.—Assessment region encompassing the states of Oregon and Washington. This is National Forest System Region 6.

Palatability.—The relish with which a particular species or plant part is consumed by an animal.

Per capita.—Per person.

Perennial.—A woody or herbaceous plant living from year to year, not dying after one flowering.

Permit.—A document authorizing use of the public lands for the purpose of grazing livestock; grazing lease.

Pesticide.—A chemical agent such as herbicide, fungicide, insecticide, etc., used for control of specific organisms.

PNC.—See Potential Natural Community.

Potential Natural Community (PNC).—The biotic community that would become established if all successional sequences were completed without interferences by humans under the present environmental conditions.

Primary production.—The conversion of solar energy to chemical energy through the process of photosynthesis. It is represented by the total quantity of organic material produced with a given period by vegetation.

Private grazing land lease rate.—Price paid for the private rental arrangement between a rancher and a landowner.

Range betterment funds.—Portion of grazing fees paid that is prescribed to be used for range improvements.

Range condition.—A term relating to the present status of a unit of rangeland in terms of specific values or potentials. Specific definitions differ by agency.

Rangeland.—A type of land on which the native vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs. Rangelands include natural grasslands, shrublands, savannas, most deserts, tundra, alpine plant communities, coastal marshes, wet meadows, riparian ecosystems, and plant communities dominated by introduced species.

Range improvement.—Any activity or program on or relating to rangelands which is designed to improve production of forage, change vegetation composition, control patterns of use, provide water, stabilize soil and water conditions, and provide habitat for livestock and wildlife. The term includes, but is not limited to, structure, treatment projects, and use of mechanical means to accomplish the desired result.

Range vegetation.—Plant species of grasses, grass-like plants, forbs, and shrubs. Range vegetation is most commonly associated with grassland and shrubland ecosystems, but is also found in many forest ecosystems.

Range vegetation management.—The management of range vegetation for multiple outputs which include herbaceous and shrub forage for both domestic and wild animals, water quality and quantity, air quality, open space, threatened and endangered plants and animals, genetic material, recreational use, plant diversity, community stability, and scenic quality. Management of range vegetation requires the application of knowledge, skills, and techniques based on ecological principles to maintain or reach established vegetative objectives while protecting fragile soils. The objectives for range vegetation management are defined in terms of species composition, condition, and the ability to provide a specified sustained level of use. Achievement of these vegetation objectives provides for an integrated mix of related resource uses and values.

Raptor.—Predatory bird.

Research.—A division of USDA Forest Service that develops scientific and technical knowledge to enhance the economic and environmental values of forest and rangelands.

Research Natural Area.—A land management category used by federal agencies to designate lands permanently reserved for research and educational purposes.

Resource value rating.—The value of vegetation present on an ecological site for a particular use or benefit; may be established for each plant community capable of being produced on an ecological site, including exotics or cultivated species.

Rest-rotation grazing system.—A grazing management scheme in which rest periods (no grazing) for individual grazing units are incorporated into a grazing rotation. Rest periods are generally the full growing season to permit seed production, establishment of seedlings, or restoration of plant vigor.

Retail weight.—Fixed percentage of carcass weight, specific to type of animal, and based on historical trends.

Riparian ecosystems.—The abiotic and biotic components found within the area defined by the banks and adjacent areas of water bodies, water courses, seeps, and springs whose waters provide soil moisture sufficiently in excess of that otherwise available locally so as to provide a more moist habitat than that of contiguous flood plains and uplands.

Rocky Mountain Region.—Assessment region that combines Northern Rocky and Southwest Assessment regions.

Roundwood.—Logs, bolts, or other round sections cut from growing stock and nongrowing stock sources such as trees smaller than 5 inches d.b.h.; stumps, tops, and limbs of growing stock trees; rough and rotten trees; dead trees; and trees that grow on land other than timberland.

Ruminant.—Eventoed, hoofed mammal of the suborder *Ruminantia*, comprising cloven-hoofed, cud chewing quadrupeds. Includes cattle, deer, and camels.

Semiarid.—A term applied to regions or climates where moisture is normally greater than under arid conditions, but still definitely limits the production of vegetation. The upper limit of average annual precipitation in the cold, semiarid regions is as low as 15 inches, whereas in warm tropical regions it is as high as 45-50 inches.

Seral.—Refers to species or communities that are eventually replaced by other species or communities with a successional sequence.

Short-duration grazing system.—Grazing management whereby relatively short periods (days) of grazing and associated nongrazing are applied to range or pasture units. Periods of grazing and non-grazing are based upon plant growth characteristics.

Sodbuster.—A provision of the 1985 Food Security Act that causes farmers to become ineligible for price-support payments, farm-storage facility loans, crop insurance, and disaster payments if the farmer plows highly erodible land that is not currently cropped.

Softwoods.—Coniferous trees, usually evergreen, having needles or scale-like leaves.

Soil bank.—A government program established by the Agricultural Act of 1956; a large scale effort to bring about adjustments between supply and demand for agricultural products by taking farmland out of production.

Southern Region.—Assessment region encompassing the states of Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Alabama, Tennessee, Kentucky, Virginia, North Carolina, South Carolina, Georgia, and Florida. This is National Forest System Region 8.

Southwest Region.—Assessment region encompassing the states of Arizona and New Mexico. This is National Forest System Region 3.

Special management pasture.—An area fenced and managed separately because of different management objectives as in riparian ecosystems.

State and Private Forestry.—A division of the USDA Forest Service that provides technical and financial assistance to states to help increase the productivity of nonindustrial private forest lands to meet projected resource demands.

Stocker cattle.—Cattle (calves and older animals) maintained primarily on pasture, range, or harvested forages to increase weight and maturity before being placed in a feedlot.

Succession.—The gradual process of progressive community change and replacement and modification of the physical environment, leading towards a stable potential natural community.

Supply.—The quantity of a product willingly offered for sale per unit of time at a specific price.

Swampbuster.—A provision of the 1985 Food Security Act that causes farmers to become ineligible for commodity program benefits if the producer drains wetlands.

Tallow.—The harder fat of sheep, cattle, etc., separated by melting from the fibrous and membranous matter naturally mixed with it, and used to make candles, soap, etc.

TAMM.—See Timber Assessment Market Model.

Timber Assessment Market Model (TAMM).—A simulation model that estimates roundwood harvest as a function of changes in timber prices and availability.

Timberland.—Forest land which is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. Areas qualifying as timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.

Timber Resource Inventory Model (TRIM).—A simulation model that projects changes in timber inventory, growth, and harvest.

Transitory range lands.—Lands managed principally for timber production but are suitable for forage production for grazing animals including wildlife and livestock during a period of time following thinning, harvest, or other timber management activity.

TRIM.—See Timber Resource Inventory Model.

Tules.—Bulrushes, large sedges, cattails, and such, collectively.

Understory.—Plants growing beneath the canopy of another plant. Usually refers to grasses, forbs, and low shrubs under a tree or brush canopy.

Urban land.—See Human-related land use.

Warm deserts.—The Mojave, Sonoran, and Chihuahuan deserts of North America; precipitation is in the form of rain.

Warm season grasses.—A grass which makes most or all its growth during the spring, summer, or fall, and is usually dormant in winter. Warm season plants usually exhibit the C-4 photosynthetic pathway, that is the dicarboxylic acid pathway of carbon dioxide assimilation.

Waterfowl.—A water bird, especially a swan, goose, or duck.

Weed.—A plant which is undesirable in light of planned land use or which is unwholesome to rangelands or range animals.

Xeric.—Having very little moisture, tolerating, or adapted to dry condition.

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